Report No. CG-D-17-90

# TECHNICAL EVALUATION OF DAYBOARD MATERIALS



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INTERIM REPORT
MARCH 1990



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Prepared for:

U.S. Coast Guard
Research and Development Center
Avery Point
Groton, Connecticut 06340-6096

and

U.S. Department of Transportation
United States Coast Guard
Office of Engineering, Logistics, and Development
Washington, DC 20593-0001

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Technical Report Documentation Page

| | | |
|---|---|---|
| 1. Report No. CG-D-17-90 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle TECHNICAL EVALUATION OF DAYBOARD MATERIALS | | 5. Report Date MARCH 1990<br>6. Performing Organization Code |
| 7. Author(s) Wayne Fisher | | 8. Performing Organization Report No. R&DC 13/90 |
| 9. Performing Organization Name and Address<br>Analysis & Technology, Inc.<br>Four John Clarke Road<br>Middletown, Rhode Island 02840<br>U.S. Coast Guard<br>Research & Development Center<br>Avery Point<br>Groton, CT 06340-6096 | | 10. Work Unit No. (TRAIS)<br>11. Contract or Grant No. DTCG39-89-C-80824 |
| 12. Sponsoring Agency Name and Address<br>Department of Transportation<br>U.S. Coast Guard<br>Office of Engineering, Logistics, and Development<br>Washington, D.C. 20593-0001 | | 13. Type of Report and Period Covered Interim<br>14. Sponsoring Agency Code |
| 15. Supplementary Notes<br>This work was performed as part of the Coast Guard's "Signal Effectiveness Project" R&D Center Project 2764. Point-of-contact: Dr. Marc Mandler USCG R&D Center, Groton, CT. 1-203-441-2615. | | |

16. Abstract

This report identifies and evaluates various materials which may be used to construct long life navigational signs (dayboards) for the U.S. Coast Guard. First, individual components of the dayboard are discussed. These include dayboard colors, substrates, backings, and adhesives. Advantages and disadvantages of each material are reviewed and summarized in tables for easy reference. Next, promising dayboard materials are combined into thirteen dayboard systems, and discussed in detail. Criteria used to predict performance of these systems include: expected life in a marine environment, ease of construction, ease of installation and servicing, safety considerations, and signal effectiveness. Life cylce costs of each system are summarized. Dayboard materials and the 13 systems are rated as "Unacceptable", "Marginally Acceptable", or "Fully Acceptable". Information from this report will provide the basis for a decision on which dayboards should be constructed and tested in the next phase of the project.

| | | | |
|---|---|---|---|
| 17. Key Words<br>aids to navigation<br>color<br>dayboard<br>sign materials | | 18. Distribution Statement<br>Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161 | |
| 19. Security Classif. (of this report)<br>UNCLASSIFIED | 20. SECURITY CLASSIF. (of this page)<br>UNCLASSIFIED | 21. No. of Pages | 22. Price |

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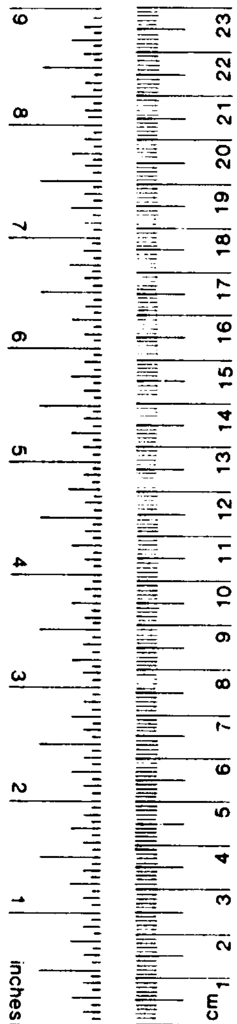
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

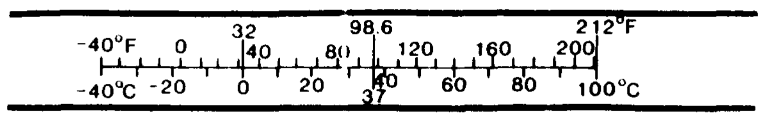
| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (WEIGHT)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (EXACT)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13.10:286




## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (WEIGHT)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 0.125 | cups | c |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (EXACT)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



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## 1.0 INTRODUCTION.

This report is the first in a series of reports which will provide information to assist the Coast Guard in designing dayboards with a field life of five years. This report lists and discusses technical advantages and disadvantages of various materials which may be used to construct long life dayboards. Individual components of the dayboard are discussed – color, substrate, backing, and adhesive – as well as combinations of materials suitable for building dayboards. Information from this report will provide the basis for a decision on which dayboards should be constructed and tested in the next phase of the 5-Year Dayboard Project.

## 2.0 BACKGROUND.

Attempts to improve dayboard design are not new. Since 1962, there have been three major Coast Guard programs with the goal of building dayboards which would provide adequate signals to the mariner and also be easy to maintain at a reasonable cost. Appendix A presents highlights of those programs. None of the programs succeeded in substantially reducing the life cycle costs of the Coast Guard's dayboard system.

The current dayboard system consists of A/C exterior plywood and fluorescent elastromeric film. These fluorescent materials have been used for more than 20 years because of their documented improvement in detection and recognition distances. Fluorescent materials, however, degrade with environmental exposure, and in most cases lose their fluorescence, and thus their signal advantage, within two years. Increasing the lifetime of dayboards may result in significant savings in personnel, ship, and material costs.

## 3.0 COLOR SELECTION

3.1 Discussion of optimum dayboard colors: Optimum or "ideal" dayboard colors would meet the following criteria:

- Be within the limits of International Association of Lighthouse Authorities (IALA) recommendations for colors to be used on aids-to-navigation.

- Maximize detection and recognition distances against water and sky backgrounds.

- Can be manufactured to show a minimal change in color after five years exposure in a Florida marine environment.

- Be commercially available at a reasonable cost.

The most difficult of these criteria to meet is the maximization of detection and recognition distances against both water and sky backgrounds. These distances are a function of numerous variables including the chromatic and luminance contrast of the dayboard against the background, height of eye of the observer, time of day, visibility conditions, and position of the sun relative to the observer. Unfortunately, there are no analytical tools which can predict the theoretical detection and recognition distance of dayboards based on these variables. These distances can be determined experimentally as was done by Mandler [Ref. 1], Mandler and Scoffone [Ref. 2], and Hanson and Dickson [Ref. 3].

These reports suggest that the "best" dayboard colors are colors that have maximum saturation and maximum brightness. In the CIE 1931 chromaticity coordinate system, this means the "best" dayboard colors would have the highest practical spectral luminance factor (capital "Y" value) and be within the color spaces recommended by IALA. This approach assumes dayboards are typically viewed against a dark background such as land or water.

The second most difficult criteria to meet is producing the colors using commercially available materials. Theoretically, there are an infinite number of colors which can be formulated. In practice, the range of colors is limited depending on the substrate chosen and the pigments and dyes available. For example, substrate materials which in their natural state are yellow, brown, or gray will never produce desired bright red and green colors. Maximum practical Y values are estimated at 22% for red non-fluorescent colors and 46% for green non-fluorescent colors. Appendix B discusses in detail the state-of-the-art in formulating dayboard colors.

3.2 Recommended dayboard colors. Any red or green color within the color limits specified by IALA and with minimum luminance factors of Y=30% for green and Y=30% for red are recommended as suitable dayboard colors. These values of Y are approximately equal to the Y values for one year weathered fluorescent films. The corresponding Munsell Value for red or green colors is approximately 6.00.

This recommendation assumes minimum fading of non-fluorescent colors, ie., the Y values of new dayboard colors will not change significantly after five years of weathering. (This

hypothesis will be tested in Task E of this project). This recommendation also assumes that any non-fluorescent color must provide detection and recognition distances at least equal to the performance of one year weathered fluorescent films. Under this assumption there are no red non-fluorescent colors that would meet the color requirements of a five year dayboard. Orange colors, as discussed below, could be satisfactory dayboard colors.

Mandler [Ref. 1] evaluated the effectiveness of several different color chips and "off-the-shelf" non-fluorescent films to find adequate colors for daytime signaling. Samples tested met IALA requirements for daytime signaling. Two "orange" and two green films showed promise as dayboard colors. Table I lists Munsell notations, CIE coordinates, and/or trade names for the colors tested. Also included in table I is an experimental film being tested by Coast Guard Headquarters as a possible dayboard material. The CIE coordinates of the test green film is not within the IALA color space for green signal colors. This is not expected to be a problem for reasons which will be explained later in this report. It is assumed that paint, film, acrylic, and foam manufacturers would be able to formulate colors to match the colors in table I.

Table I Recommended Dayboard Colors

| Color | Trade Name | Munsell Notation Hue/Value/Chroma | CIE Coordinates 1931 x | D65 y | 45/0 Y |
|---|---|---|---|---|---|
| Red | Fascal 911 Orange | 2.5YR 6.3/18.8 | 0.572 | 0.405 | 0.339 |
| Red * | Fasign | 7.5 R 4.9/19.5 | 0.627 | 0.333 | 0.189 |
| Green | N/A | 7.5G 6/10 | 0.242 | 0.434 | 0.339 |
| Green | N/A | 5.6G 6.12/13.7 | 0.221 | 0.485 | 0.357 |
| Green * | Fasign | 7.5GY 6.6/15.3 | 0.351 | 0.594 | 0.379 |
| * Experimental film for Coast Guard Headquarter's field test | | | | | |

3.3 <u>Justification for recommended colors.</u> The recommended dayboard colors are based on a review of the literature on dayboard color selection, a survey of industry to determine potential sources of supply for dayboard colors, an estimate of visual detection and recognition performance, and the specified requirements for dayboard colors. Appendix C is a bibliography of literature related to dayboard colors.

One factor considered in recommending colors is the need to choose colors for which physical samples existed. This was necessary for two reasons: (1) No theoretical model is available to predict the signal effectiveness of colors based on either Munsell notation or CIE coordinates. (2) Companies require physical samples to formulate custom dayboard colors

The colors in table I are also recommended because they have been previously tested as dayboard colors (except for the Headquarter's test film). Test results indicate these colors may provide a signal at least equal to, if not better than, one year weathered fluorescent film.

## 4.0 SUBSTRATE SELECTION.

Substrates are materials containing color pigments or dyes. Primary evaluation criteria for substrates include: estimated life in a marine environment, potential effect on the environment, conspicuity of substrate, and ease of handling.

4.1 Types of substrates. The general types of substrates considered as possible dayboard materials are: marine coatings (paints), elastomeric vinyl films, plastics, and fabrics.

4.1.1 Marine coatings [1]. Marine coatings are thin films of polymeric or metallic materials used to protect the surface of materials exposed to the marine environment. For dayboards, the coating must also present the proper navigational signal to the mariner. The surface to be protected on a dayboard is the backing. Typical coating films consist of polymers, inorganic compounds, and additives. Figure 1 illustrates the principal components of a coating.

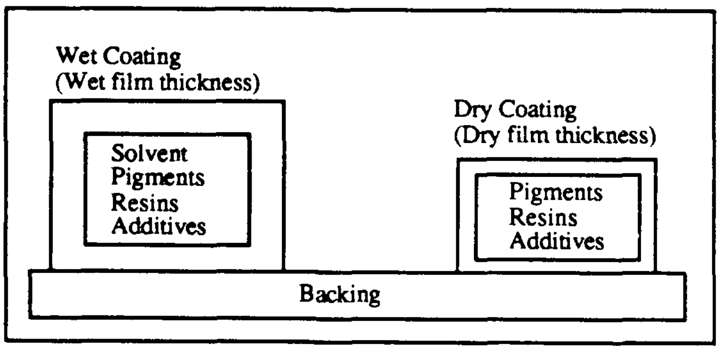


Figure 1. Principal Components of a Coating

1 For an excellent technical discussion of marine coatings, see Marine Coatings by Henry R Bleile and Stephen Rodgers, Federation Series on Coatings Technology, March 1989. [Ref. 4]

Marine coatings are applied in liquid form by brushing, spraying, or rolling. A dry, hard coating is formed when the solvent evaporates and by chemical reactions in the film. An important requirement for Coast Guard dayboards is that the components in the substrate are not harmful to dayboard personnel or the environment. Table II lists advantages and disadvantages of marine coatings as dayboard materials.

Table II Advantages and Disadvantages of Marine Coatings

<u>Advantages of Marine Coatings</u>

- Cost-effective technology for control of corrosion in the marine environment
- Extends service life of materials used as backings for dayboards
- May be pigmented to provide optimum dayboard colors
- Mature, proven technology
- Application techniques (brushing, spraying, rolling) familiar to Coast Guard personnel
- Off-the-shelf coatings available
- Numerous sources of supply for follow-on procurements
- Can be procured competitively

<u>Disadvantages of Marine Coatings</u>

- Need to meet stringent environmental, health, and safety regulations
- Quality assurance of coatings essential for maximum performance
- Surface preparation of backing is critical
- Spray metalized coatings and perhaps polyurethanes would require centralized production of dayboards or contracting out of operation

In selecting a marine coating it must be understood that the range of service life for a given type of coating is great. Factors which heavily influence the life of the coating include: coating manufacturer's experience, specific coating formulation, quality of ingredients in the coating, type of surface preparation, and skill of the applicator. The next sections discuss specific properties of the types of marine coatings considered for use on dayboards.

4.1.1.1 Epoxies. Epoxy coatings are formed by the chemical reaction of an epoxy resin with a "curing agent". Epoxy coating films are strongly resistant to most chemicals, make excellent anticorrosion coatings, and are one of the principal materials used to control corrosion in the marine environment [Ref 1, p 17.] Epoxies do chalk when exposed to intense sunlight and are typically used with cosmetic topcoats that have higher resistance to sunlight. Coast Guard buoys, for example, use an epoxy primer with vinyl - alkyd as a topcoat. Clear polyurethane or acrylic can also be used as a topcoat to minimize the effect of sunlight on epoxy coatings.

Expected service life of an epoxy paint system is 6 years on properly prepared aluminum or galvanized steel and 5 years on plywood, fiberboard, or fiberglass reinforced plastic.

4.1.1.2 Polyurethanes. Polyurethane coatings are formed by a chemical reaction between polyurethane resins and curing agents. These coatings form tough, chemically resistant surfaces, and make particularly good, high gloss cosmetic finishes. The high gloss is diminished when exposed to intense sunlight. The durability of polyurethane coatings and their ability to be pigmented to desired colors, are two features required of dayboards.

Four types of polyurethane coatings evaluated for use on dayboards are:

- Sherwin Williams Hi-Bild Aliphatic Polyurethane Enamel
- Sherwin Williams Polane High Solid Enamel
- Development Associates Z-4551 Instant Set Elastomer
- Development Associates Z-464X-T Diaflex Topcoat

All of the above products, used with appropriate primers, can be used as protective coatings for a variety of dayboard backings, including fiberglass reinforced plastics, metals, and plywoods. Each product, when applied in accordance with the manufacturer's instructions, can be expected to perform well in the marine environment. The Development Associate products in particular, were developed exclusively as protective coatings for Tideland buoys. The

manufacturer's claims of high performance are supported by four years of field experience and by independent tests by Woods Hole Oceanographic Institute.

All of the above products also have limitations as potential dayboard substrates. The Hi-Bild Aliphatic Enamel for example, has a Volatile Organic Compounds (VOC) of 4.18 lbs/gal and Polane's VOC is 4.4 lbs/gal. EPA regulations being considered may limit the maximum VOC to 2.0 lbs/gal. These regulations apply mainly to how the product is used. What this means for dayboards is that the dayboard itself when installed in the field will not be a hazard to the environment. However, constructing the dayboard may violate EPA regulations. The adoption of the 2.0 lbs/gal standard still has a number of political hurdles to clear. Until the issue is resolved, marine coatings with VOC's exceeding 2.0 lbs/gal can only be considered marginal dayboard materials.

A limitation on the Z-464SX-T Diaflex Topcoat is that appropriate dayboard colors would need to be formulated. (Coast Guard buoy green is a standard product). The price of the formulation is estimated at $1000 which includes in-house accelerated weathering tests.

The Polane High Solid Enamel is not recommended for exterior use on plywood. In areas having long and strong sun intensity, direct exposure can lead to chalking, low gloss, and color fade.

Besides the above products, clear polyurethane or acrylic coatings are often used as the topcoat in a multi-coat system. A three coat system (one coat inorganic zinc, one coat high build epoxy, and one coat polyester urethane) applied over a near-white blast steel has an estimated life of six years in a marine environment [Ref. 4, p. 20].

4.1.1.3 Vinyls. Vinyl resins are formed by the polymerization of vinyl compounds. Vinyl coatings have excellent resistance to many chemicals and to the effects of weathering. Vinyl siding on houses for example is known for its long life. Vinyl resins may also be manufactured into elastomeric films. Section 4.1.2 will discuss vinyl films as dayboard materials.

4.1.1.4 Sprayed metalized coatings. These coatings came into general marine use in the late 1970's and early 1980's. They are formed by melting a metal and spraying it onto a surface to be protected. The two most commonly used metals are zinc and aluminum with aluminum being favored for marine service because of its longer life and low weight.

For maximum possible service life, sprayed metal coatings are topcoated with organic coatings (typically vinyls and epoxies). When applied to a near-white blast cleaned steel surface, a 10-15 mil aluminum coating with organic topcoats has an estimateed life of 15 years. [Ref. 4, p. 21]

The technical issue with using sprayed metalized coatings on dayboards is whether or not the aluminum in its molten state can be pigmented to proper dayboard colors. The only U.S. manufacturer using this technology is National Thermal Spray on Long Island, NY. When contacted, they did not believe it possible to pigment the aluminum.

4.1.2 Elastomeric vinyl film. The current dayboard substrate is fluorescent elastomeric film. Coast Guard Specification G-EOE-339B describes the expected performance of this film in the marine environment. The major problem of this film is severe color fading, particularly the red film, after two years exposure to intense ultra-violet radiation. One possible solution to designing a long life dayboard is to develop brightly colored red and green non-fluorescent films.

Fasign developed such films to be used as part of a U.S. Coast Guard Headquarter's project to increase the life of dayboards in the Seventh Coast Guard District (Miami, FL). Dayboard personnel in CGD7 received 24,000 sq ft of elastomeric vinyl film which is to be applied to either aluminum or marine grade plywood backings. The estimated life of the film is 5 years. While not as bright as fluorescent film, the conspicuity of the films is expected to be good. Since the film has the same physical properties as fluorescent film (except for brightness), it is a familiar material to the field personnel and is therefore easy to work with.

One minor problem is that the color coordinates of the green film do not fall within the recommended IALA color space for colors to be used on aids-to-navigation. For example, the boundary between the green and yellow boxes on the CIE 1931 color diagram is x = .313. The x-coordinate for the green film sample is x = .351. This is not expected to be a problem for the following reasons: (1) mostly all mariners would agree that the color of the sample is green; (2) less than 0.5% of dayboards are yellow, so there is very little probability of the test green sample being confused with yellow dayboards; (3) IALA recommendations are not obligatory and do not generally apply to dayboards; and (4) the color has been approved by Headquarter personnel for field testing.

The progress of the field test of vinyl elastomeric film will be monitored and results will be documented as part of the Five Year Dayboard Project.

4.1.3 Plastics.

4.1.3.1 Fiberglass reinforced plastic (FRP).

Fiberglass reinforced plastic (FRP). FRP is a fiberglass reinforced composite used in the sign industry as an alternative to aluminum. Two types considered as dayboard substrate materials are "Polyplate" manufactured by Sequentia, Inc. and "Extren" made by Morrison Plastics. When contacted as to the feasibility of pigmenting FRP to acceptable dayboard colors, both companies stated dark, "highway green" and "stop sign red" are available, but pigments are not available to formulate bright dayboard colors. For this reason FRP is not suitable as a substrate material. It is an excellent candidate as a backing material. Section 5.1 discusses FRP in detail.

4.1.3.2 Surlyn foam. Surlyn is an ionomer resin manufactured by DuPont. Its most relevant properties to the dayboard project include excellent weatherability, custom colors, lightweight, excellent adhesion, and versatility in processing. Manufactured under the trade name "Softlite" by the Gilman Corporation in Gilman, Ct, its durability is well documented in the literature including work sponsored by the Coast Guard. Coast Guard buoys are currently being made with Softlite. 113 dayboards using Softlite as the backing and fluorescent film as the substrate have been field tested by the R&D Center. The results of the field test are undocumented. A very attractive feature of Surlyn foam as a dayboard material is its ability to double as a substrate and a backing. Its lightweight (4 pounds for a 3SG) makes it easy to handle and install in the field. Technically there appears to be no disadvantages to using Surlyn foam to construct dayboards. Note: the history of using foam for Coast Guard aids-to-navigation is checkered. Foams other than Surlyn foam have not performed well in the marine environment and are not recommended.

4.1.3.3 Acrylic sheeting. Cast acrylic sheets have been used in the sign and display industry since the 1950's. The Coast Guard Dayboard Evaluation Project in 1970 concluded that acrylic is unsuitable as a dayboard material due to its tendency to become brittle and shatter at low temperatures. Since 1970, advances have been made in the fabrication of acrylic to the point where sheeting is available today which is claimed to be 2 1/2 times as rigid as ordinary acrylic sheeting. One such product is LumaSite manufactured by American Acrylic Corporation on Long Island, NY. Made from pure acrylic, the material is advertised as shatterproof and claims to not lose strength or color when exposed for long years to the most severe outdoor conditions. Custom dayboard colors may be available and the material can double as a substrate and backing. The estimated life of this material in the marine environment is 6 years. Considering that Coast Guard

buoy lenses are also made from acrylic resin and do not fade significantly, the estimated life seems reasonable. The manufacturer will also warranty the product for 7 years. Disadvantages of the material is that it may cause skin irritations when handled and the unavailability of test data to support the manufacturer's claims of performance.

4.1.4 Fabrics. The existence of many brightly colored fabrics used in the fashion industry led to the investigation of fabrics as possible dayboard materials. The basic idea would be to design a dayboard frame to which properly colored fabrics would be attached. Advantages of a fabric dayboard would include lightweight, brightly colored fabrics which could easily be discarded and replaced in the field. The technical issue is how long the fabric would survive in a marine environment. To estimate the service life, information was solicited from major textile manufacturers. No manufacturer would recommend their product for use in the marine environment. Average estimated service life would range from 6 months to one year. The main failure mode would be the rapid fading of the fluorescent pigments used to achieve highly conspicuous colors. This situation would be no better, and perhaps even worse, than the present situation with fluorescent film.

4.2 Summary of advantages/disadvantages of dayboard substrates. Table III summarizes the advantages and disadvantages of specific materials which have been considered as dayboard substrates.

Table III Advantages and Disadvantages of Dayboard Substrates

| Potential Substrate | Advantages | Disadvantages |
|---|---|---|
| Hi-Bild Polyurethane or Epoxy paints systems | High performance<br>Excellent color retention<br>Long life | High VOC<br>Harmful vapors<br>May lose gloss<br>High QA required |
| Polane High Solids Enamel | Excellent performance<br>Wide range of colors | High VOC<br>Harmful vapors<br>No good on wood |
| Instan_Set | 100% solids<br>Developed for buoys<br>Long life | Harmful vapors<br>Needs topcoat for color. |
| Diaflex-Topcoat | Excellent weathering<br>Field tested on buoys | R&D for custom color |
| Sprayed metalized coatings | 15 year life | Cannot be colored |
| Elastomeric vinyl film (non-fluorescent) | Custom colors available<br>24,000 sq ft in field test<br>"Best" available colors<br>Highest Munsell value<br>Familiar product to personnel | Green not IALA<br>No Coast Guard QA |
| Fiberglass reinforced plastic FRP (Polyplate) | Engineered for sign industry<br>Extensive testing as backing<br>Weather resistant<br>Long life - 10 yr warranty | Bright colors unavailable |
| Surlyn foam (Softlite) | Excellent documentation<br>Meets CG Buoy Specification<br>Tested by Woods Hole<br>Custom dayboard colors<br>113 Dayboards tested by CG R&DC<br>Combined substrate & backing | R&D for custom color |
| Acrylic sheeting (LumaSite) | Engineered for sign industry<br>Combined substrate & backing<br>Long life - 7 year warranty<br>Custom dayboard colors | Sparse test data,<br>May irritate skin<br>R&D for custom color |
| Fabrics | Brightly colored, Lightweight, Disposable | Very short life<br>Needs frame |

4.3 Rating of substrates. Based upon the information discussed in section 4.1 and summarized in section 4.2, substrates are rated in table IV as fully acceptable, marginally acceptable, or unacceptable dayboard materials. Fully acceptable means the materials are readily available to construct prototype dayboards for further testing and there is a high probability that the materials will last five years in a marine environment. Marginally acceptable means the materials could be procured to construct prototype dayboards but additional R&D efforts must be completed to formulate optimum dayboard colors. Marginally acceptable may also mean that there is some concern due to lack of test data that the materials may not last five years in a marine environment. Unacceptable means the material is not suitable for use as a dayboard component.

Table IV. Rating of Dayboard Substrates

| Substrate | Rating |
|---|---|
| Epoxy coating system | Marginally Acceptable |
| Hi-Bild Polyurethane | Marginally Acceptable |
| Polane High Solids | Marginally Acceptable |
| Instan-Set | Marginally Acceptable |
| Diaflex-Topcoat | Marginally Acceptable |
| Sprayed metalized coatings | Unacceptable |
| Elastomeric vinyl film (non-florescent) | Fully Acceptable |
| Elastomeric film (fluorescent) | Unacceptable |
| Fiberglass reinforced plastics | Unacceptable (as substrate) |
| Surlyn foam | Fully acceptable |
| Acrylic sheeting | Fully acceptable |
| Fabrics | Unacceptable |

## 5.0 BACKING MATERIAL SELECTION.

The backing is the material to which the substrate is applied. Technical evaluation criteria for backings include: estimated life in a marine environment, ease of mounting, safety considerations, ease of construction, and compatibility with substrate.

5.1 Types of backings. Possible dayboard backings include: plywoods, metals, plastics, and fiberboard.

5.1.1 Plywoods. The Coast Guard Specification for Manufacturing Dayboards (G-ECV-300B dated May 12, 1989) specifies the standard backing as either 3/8 inch or 1/2 inch A/C exterior grade plywood. This grade of plywood in the marine environment has a service life between 2 to 3 years depending on location. (In practice, Coast Guard units will use lower grade plywoods in areas where dayboards are frequently replaced due to collisions or flooding and higher grade plywoods for larger dayboards and range boards).

For long life dayboards, marine grade plywood is recommended. With edge sealing, the estimated service life of 1/2 inch marine grade plywood is 5 years. This agrees with the experience of Coast Guard units in CGD13 where marine grade plywood is used to build dayboards. Advantages of plywood include: requires no painting prior to application of films, mounts easily using simple hardware, is rigid, and is a familiar product to dayboard personnel. Possible disadvantage is that the ultimate durability is not equivalent to metals and plastics.

5.1.2 Aluminum. Aluminum is strong, resilient, resists bending and damage, and to a large degree is corrosion resistant. It is the most popular sign backing material mainly for its long life in normal use. As a traffic sign backing material, it can be stripped, refurbished, and used over and over again. For this reason, many traffic engineers feel aluminum is the most economical sign backing in the long run.

On the negative side, the preparation of aluminum before applying films or paints generates hazardous wastes. For centralized production of dayboards, this is a potential problem which can be managed. For the present method of manufacturing dayboards, the stripping and degreasing of aluminum can present problems to individual dayboard shops. Problems of this nature have already occurred in the Headquarter's field test of non-fluorescent film in CGD7. Another negative - the price of aluminum can vary significantly depending on market conditions.

The track record of aluminum dayboards (with fluorescent film) in the Coast Guard is good. Aluminum dayboards deployed in 1985 as part of a Headquarter's "Dayboard Improvement Project" have been refurbished successfully by dayboard personnel in CGD13.

5.1.3 Galvanized steel. Galvanized steel has performance similar to aluminum sheeting. It is strong, resists bending, and requires minimum preparation to paint or apply film. The disadvantages are: (1) it may rust eventually in damaged areas or upon long exposure; (2) it's heavy and may be difficult to handle and install; (3) pricing history is unstable.

5.1.4 Plastics. Three plastics considered as substrate materials are also evaluated as possible dayboard backings.

5.1.4.1 Fiberglass reinforced plastic (FRP). There are many types of FRP products on the market. As sign blanks the two top competitors appear to be Sequentia, Inc. (Polyplate) and Morrison Plastic (Extren). The difference between the products is that Extren is a more universal product, used in many applications including gratings for oil platforms at sea. Since people would be walking on Extren decks, compression strength is important. Polyplate is manufactured mainly as a sign backing material. As a sign, it does not need to be as strong as Extren with regards to compression strength. This reduces the price of Polyplate to half the price of Extren ($1.35/sq ft vs $3.38/sq ft). Since Polyplate meets the requirements for a five-year dayboard at one-third the cost of Extren, only Polyplate is discussed in detail.

Polyplate was engineered as a sign backing materials to offer a low price alternative to aluminum signs. Since 1977, the State of Ohio has tested Polyplate extensively with excellent results. They currently have over 500,000 sq ft of material in use. Twenty-two other states are testing Polyplate. In 1985, the Coast Guard purchased 235 Polyplate dayboards from Federal Prison Industries to be used with the Dayboard Improvement Project and Articulated Light Project. Observations from these field tests seem to support the claim that Polyplate can survive for at least five years in the marine environment. Sequentia warranties Polyplate for 10 years. Polyplate is non-conductive and will not rust, rot, or peel. It accepts heat-activated or pressure sensitive sheeting and can be fabricated with present Coast Guard dayboard shop equipment. Polyplate meets the requirements of the Society of Plastics Industry's "Recommended Traffic Control Sign Panel Specification".

Advantages of Polyplate as a dayboard backing include: long life, easy fabrication, lightweight (3SG weights 9 lbs), no environmental concerns, compatibility with present dayboard manufacturing processes, and stable price history. Possible disadvantages include: (1) Polyplate's inability to yield by bending which can result in shattering of the dayboard; (2) Ohio engineers have noted a tendency for the area around the washer to shear when Polyplate is loaded from behind; (3) A minor concern is that skin irritations can occur if proper clothing is not worn while cutting the material. This problem is avoided if pre-cut dayboard shapes are ordered from the manufacturer.

5.1.4.2 Surlyn foam. Surlyn foam has been tested previously by the Coast Guard as a possible backing material. A letter report dated 27 April 87 from the R&D Center to G-ECV documents the foam dayboard development work accomplished at the R&DC [Ref. 5]. The report concludes that Surlyn foam is a suitable material for dayboards due to its lightweight, toughness, and compatibility with elastomeric film. In 1987, Gilman Corporation constructed 113 prototype foam dayboards - fluorescent film as the substrate - to be field tested by the Coast Guard. Complete results of the field test are unavailable. Preliminary results seem to indicate the foam weathers well and would probably last a minimum of five years in the marine environment.

Section 4.1.3.2 discussed Surlyn foam as a possible dayboard substrate material. Advantages of Surlyn foam as a backing material include: long life (at least 5 years), ease of installation (3SG weights 4 pounds), no assembly required (dayboards shipped ready to mount), and ability of Surlyn foam to double as a substrate and backing. Technically, there appear to be no disadvantages to using Surlyn foam as a dayboard backing.

5.1.4.3 Acrylic sheeting. LumaSite acrylic sheeting can also be used as a backing material. LumaSite's performance as a backing material would be expected to be comparable to fiberglass reinforced plastic.

Advantages of LumaSite as a backing material include: long service life (estimated at 6 years), lightweight (3SG weights 8 pounds), and ability of LumaSite to double as a substrate and backing. Disadvantages include: possibility of failing by shattering, possible skin irritations when handled, and lack of available test data on use of LumaSite as a sign backing.

5.1.5 Fiberboard. Medium density fiberboard is a composite wood based product which is gaining acceptance as a low price alternative to medium density overlaid plywoods. The fiberboard with potential as a dayboard backing is "medex" manufactured by Medite Corporation in Medford,

Oregon. This material has been tested as a highway sign for over six years with good results. "Medex" is compatible with films or paints. It is available either pre-primed or unfinished. Advantages as a dayboard backing material include: possible 5 year life if adequately protected, excellent surface for applying paints or films, low price alternative to higher grade plywoods. Disadvantages include: limited test data in a marine environment, and the need to protect both sides of the sign from the environment.

5.2 Summary of advantages and disadvantages of dayboard backing. Table V summarizes the advantages and disadvantages of possible dayboard backings.

Table V  Advantages and Disadvantages of Dayboard Backings

| Potential Backing | Advantages | Disadvantages |
|---|---|---|
| Marine grade plywood | Strong<br>5 year life<br>Simple preparation<br>Extensive field use<br>May be reused | Long term life is not as great as metals |
| Aluminum | Very Strong<br>Resists corrosion<br>Previously tested<br>Very long life | Generates hazardous waste<br>Unstable pricing<br>High shipping costs |
| Galvanized steel | Very strong<br>Very long life<br>Resists corrosion | Hard to handle<br>Unstable pricing<br>High shipping costs |
| Fiberglass reinforced plastic (FRP) "Polyplate" | Engineered for sign industry<br>Extensive field tests since 1977<br>Weather resistant<br>Long life - 10 year warranty<br>Stable pricing<br>Lightweight - 1 lb/sq ft<br>Tested by Coast Guard | Tendency to fracture<br>May irritate skin<br>Possible sole source<br>Procurement |
| Surlyn foam (Softlite) | Excellent documentation<br>Meets CG Buoy Specification<br>Tested by Woods Hole<br>Lightweight - easy to handle & install<br>113 Dayboards tested by CG R&DC<br>Combined substrate & backing | Possible sole source<br>Procurement |
| Acrylic sheeting (LumaSite) | Engineered for sign industry<br>Combined substrate & backing Long life - 7 year warranty<br>Custom dayboard colors | Sparse test data<br>May irritate skin<br>Possibility of shattering |
| Fiberboard (Medex) | Used in highway signs for 6 yrs.<br>Pre-primed<br>Compatible with films or paints<br>Low price alternative to HDOP. | Limited test data in marine environment |

5.3 Rating of dayboard backings. Based upon the information discussed in section 5.1 and summarized in Section 5.2, dayboard backings are rated in table VI as fully acceptable, marginally acceptable, or unacceptable dayboard materials. The definition of these ratings are identical to those used to rate substrates in Section 4.3.

Table VI Rating of Dayboard Backings

| Backing | Rating |
| --- | --- |
| 1/2 inch marine grade plywood | Fully Acceptable |
| 1/2 inch exterior A/C plywood | Unacceptable |
| 1/10 inch 5052 aluminum sheeting | Fully Acceptable |
| 14 gauge galvanized steel | Unacceptable |
| .135 inch fiberglass reinforced plastic | Fully Acceptable |
| 1 1/2 inch Surlyn foam | Fully Acceptable |
| 1/8 inch acrylic sheeting | Fully Acceptable |
| 1/2 inch medium density fiberboard | Marginally Acceptable |

## 6.0 ADHESION SELECTION.

Adhesives are used to bond the dayboard substrate to the backing. The only potential substrate requiring special adhesives is elastromeric film. Two types of adhesives - heat activated and pressure sensitive - have been used to effectively bond fluorescent film to properly prepared plywood, aluminum, foam, and FRP. Properties of each adhesives are discussed next.

### 6.1 Types of Adhesives

6.1.1 Heat-activated. The heat-activated adhesive currently used on Coast Guard elastromeric film is a tach-free adhesive activated by applying heat in excess of 175 degrees Fahrenheit to the film as in the heat-vacuum process used in sign fabrication. The advantage of heat-activated adhesives is excellent adhesion between the film and backing. With plywood, for example, it is not uncommon for the bond between the film and plywood to be stronger than the internal bond between the plys of the wood. The disadvantage of heat-activated adhesives is the initial expense and upkeep of heat-applicator machines. The Thirteenth Coast Guard District conducted a detailed cost/benefit study to decide whether to purchase a heat-applicator machine. They concluded that

for the way CGD13 constructs dayboards (units construct their own dayboards) it is more cost effective to use pressure sensitive film. Note - for large dayboard shops such as St. Louis, MO (7000 dayboards/year), where dayboard production is centralized, heat-applicators are more cost effective. Approximately 90% of the Coast Guard uses heat-activated film.

6.1.2 Pressure sensitive. Pressure sensitive adhesives used on Coast Guard elastromeric film is an aggressive tach type requiring no heat, solvent, or other preparation for adhesion to smooth, clean surfaces. Outside of CGD13, its main use is to construct emergency dayboards when heat-applicator dayboards are not available. It is also used by local Coast Guard units who construct their own dayboards. The advantage of pressure sensitive adhesives is that they can be used anywhere to construct dayboards. The disadvantage is that the backing must be properly prepared for maximum performance of the adhesive. There have been reported cases of pressure sensitive film "falling off of dayboards" within 24 hours after the dayboards were constructed. When investigated, it was determined that using damp plywood - not the adhesive - caused the premature failure of film.

## 7.0 DAYBOARD SYSTEMS.

The most effective method to design a dayboard is to employ a systems engineering approach. Systems engineering looks at every stage of producing dayboards – from purchase of raw materials to installing and eventually replacing the dayboard in the field. This "cradle-to-grave" approach ensures that all aspects of the dayboard system are considered when deciding whether or not to implement a new system. Systems engineering requires analyzing dayboards as a system as opposed to individual components. A dayboard system is defined as the combination of appropriate substrates and backings with potential to serve as Coast Guard dayboards. Table VII lists possible dayboard systems.

Table VII Possible Dayboard Systems

| | | BACKINGS | | | | | |
|---|---|---|---|---|---|---|---|
| | | Acrylic | Aluminum | Fiberboard | FRP | Marine Grade Plywood | Surlyn Foam |
| SUBSTRATES | Acrylic | X | – | – | – | – | – |
| | Film | – | X | X | X | X | X |
| | Surlyn Foam | – | – | – | – | – | X |
| | Paint Systems | – | X | X | X | X | – |
| X = Possible dayboard system | | | | – = Not feasible | | | |

Table VIII lists the specific dayboard systems considered as "Five Year Dayboards".

Table VIII Specifications for Dayboard Systems

| | System |
|---|---|
| A. | .125 inch LumaSite acrylic sheeting with dayboard color impregnated into the acrylic |
| B. | .100 inch 5052 aluminum with Fasign film |
| C. | .100 inch 5052 aluminum with epoxy or polyurethane paint system |
| D. | .50 inch medex fiberboard with Fasign film on one side, protective coating on reverse side, and edge sealing |
| E. | .50 inch medex fiberboard with epoxy or polyurethane paint system on one side, protective coating on reverse side, and edge sealing |
| F. | .135 inch fiberglass reinforced plastic (Polyplate) with Fasign film |
| G. | .135 inch fiberglass reinforced plastic (Polyplate) with epoxy or polyurethane paint system on one side |
| H. | .50 inch marine grade plywood with Fasign film and edge sealing |
| I. | .50 inch marine grade plywood with epoxy or polyurethane paint system and edge sealing |
| J. | 1.50 inch Surlyn foam with dayboard color impregnated into the top layer of foam |
| K. | 1.50 inch Surlyn foam with Fasign film |
| L. | .50 inch particle board covered with 40 mils of 100% solids Instan-Set polyurethane on all sides and topcoated with 3-5 mils of Diaflex polyurethane |
| Notes: | (1) All dayboards to include retro reflective film of appropriate width as per Coast Guard Dayboard Specification<br>(2) Present dayboard system consisting of .50 inch A/C exterior plywood with fluorescent film will also be evaluated to establish basis for comparing performance of other systems. |

Four tasks are necessary to evaluate a dayboard system:

(1) Evaluate dayboard benefits
(2) Determine life cycle costs
(3) Discuss advantages and disadvantages of competing systems
(4) Rate dayboard systems.

7.1 Evaluation of technical benefits. The criteria used to evaluate the benefits of each dayboard system include: estimated service life in a marine environment, ease of constructing and installing the dayboard, safety considerations, and signal effectiveness. Discussing these criteria will answer the five most important questions concerning a new dayboard system:

(1) Will it survive in a marine environment?
(2) Is it easy for dayboard shop personnel to build?
(3) Is it easy for field personnel to install and service?
(4) Is it safe to handle and is it safe for the environment?
(5) Does it meet operational requirements?

To answer these questions, information was gathered from a number of sources. First, manufacturers of each possible dayboard material submitted technical data sheets and any other supporting documentation on their product. A&T engineers reviewed these specification sheets and available test data to estimate the life of each dayboard in a marine environment. Next, where practical, manufacturers were visited at their sites to obtain additional information about specific products. Another valuable source of information consisted of numerous phone calls to Coast Guard dayboard personnel who manufacture, install, and service dayboards. Coast Guard reports of previous efforts to test dayboards provided additional data which was useful to analyze the merits of various dayboard systems. Finally, Coast Guard and industry experts are consulted for their advice on the potential of various materials to meet dayboard requirements.

Section 7.3 discusses the advantages and disadvantages of each dayboard system identified in table VIII.

7.2 Summary of life cycle costs. The life cycle costs of a dayboard system include both "one-time" costs and "recurring annual" costs. One time costs include such items as purchasing new equipment, disposing of old equipment, and training. Recurring annual costs include constructing dayboards, maintaining equipment, servicing dayboards, and associated labor. A separate report

Table IX Life Cycle Cost

| SYSTEM | NET PRESENT VALUE | NORMALIZED VALUE |
|---|---|---|
| 1. FRP/FILM | $3,027,716 | .496338 |
| 2. FIBERBOARD/FILM | $3,259,149 | .534277 |
| 3. PLYWOOD/FILM | $3,932,911 | .644728 |
| 4. FIBERBOARD/PAINT | $4,393,590 | .720248 |
| 5. FRP/PAINT | $4,776,622 | .783039 |
| 6. ACRYLIC | $4,917,407 | .806118 |
| 7. ALUMINUM/FILM | $4,960,686 | .813213 |
| 8. PLYWOOD/PAINT | $5,170,427 | .847596 |
| 9. SURLYN FOAM/FILM | $5,177,841 | .848812 |
| 10. SURLYN FOAM | $5,651,314 | .926429 |
| 11. ALUMINUM/PAINT | $5,678,062 | .930814 |
| 12. PRESENT SYSTEM | $6,100,101 | 1.000000 |
| 13. POLYURETHANE | $7,420,603 | 1.216472 |

details the life cycle cost of each dayboard system. For easy reference, the estimated life cycle costs of each system are summarized in table IX. Results are reported as "net present value" and as a number which has been normalized to the cost of the present dayboard system.

7.3 Advantages and disadvantages of dayboard systems. This section discusses the merits and problems of each dayboard system listed in table VIII. Systems are discussed in alphabetical order. Discussions are based on the combined lists of advantages and disadvantages for dayboard backings and substrates, information from the life cycle cycle cost analysis, and conversations with Coast Guard personnel. Table X summarizes the major advantages and disadvantages of each system.

7.3.1 A/C plywood with fluorescent film. This is the currently installed system. Its main advantages is that new fluorescent film can be shown to have the highest detection and recognition ranges of any dayboard system. The fluorescent film may also provide a "superior" signal when visibility is reduced at dusk and dawn. However, the original conversion of dayboards to fluorescent film was made without a complete scientific base. Small, brightly colored dayboards were initially installed with the belief they would be easy to handle, more effective as signals, and less expensive to maintain. They have proven difficult to supply and store, only marginally more effective due to fading, and expensive to maintain [Ref. 6]. The average life of fluorescent dayboards is estimated at 2 years or less. A detailed Second Coast Guard District study, for example, estimated the life of dayboards as 1.35 years. The net present value to support the current system for the period 1992 - 2002 is $ 6.1M. This compares to $ 5.2M for the next most expensive system and $ 3.0M for the least expensive system.

7.3.2 Acrylic sheeting. Cast or extruded acrylic sheeting is extremely weatherable and should retain its color well over 5 years. LumaSite discussed previously is warranted for 7 years. Both types of sheeting can possibly be colored to provide appropriate dayboard signals. Another advantage of acrylic sheeting is that it may be able to serve as both a backing and substrate. This eliminates a step in the production of dayboards and thus represents significant cost savings. A temporary disadvantage of acrylic sheeting is the initial R&D costs to develop custom dayboard colors. Manufacturers are apparently unwilling to commit any development funds to properly formulate dayboard colors. Unlike most color formulations, the dual requirements of high saturation and maximum brightness for dayboard colors, stretches the capabilities of most acrylic manufacturers. For example, American Acrylic was contracted to provide sample LumaSite sheets to match the colors of the Fasign film being tested in CGD7. They were unable to match the color. Other disadvantages of acrylic sheeting include: lack of available test results, possible irritation of

Table X  Major Advantages and Disadvantages of Dayboard Systems

| System | Advantage | Disadvantage |
|---|---|---|
| A/C plywood with fluorescent film | Present system<br>Excellent conspicuity of new film | 2 year life<br>Costly<br>Many be over designed |
| Acrylic sheeting | Excellent life (6+ years)<br>Lightweight (8 lbs 3SG)<br>Custom colors | Sparse test data<br>May irritate skin<br>May shatter |
| Aluminum with film | Standard sign materials<br>Long life (5 years)<br>Previously tested by CG | Difficult to construct<br>Unstable pricing<br>Theft of aluminum |
| Aluminum with paint | Excellent life (6 years)<br>Custom colors | Quality control<br>Unstable pricing<br>Theft of aluminum |
| Fiberboard with film | Excellent surface<br>Minor impact on CG<br>Reasonable cost | Limited test data in marine environment<br>Extra fabrication step |
| Fiberboard with paint | Excellent surface<br>Pre-primed<br>Custom colors | Quality control<br>Limited test data in marine environment |
| Fiberglass reinforced plastic with film | Long life (5 years)<br>Lightweight (9 lbs 3SG)<br>Easy fabrication<br>Precut blanks | Can shatter in collisions |
| Fiberglass reinforced plastic with paint | Excellent life (6 years)<br>Lightweight (9 lbs 3SG)<br>Custom colors | Can shatter in collisions<br>Quality control |
| Marine plywood with paint | Easy to implement<br>Long life (5 years)<br>Easy fabrication | Availability of plywood |
| Marine plywood with paint | Long life (5 years)<br>Custom colors | Quality control<br>Availability of plywood |
| 100% solids polyurethane | Excellent life (6+ years)<br>Custom colors<br>Zero VOC | Start up costs<br>R&D for custom colors |
| Surlyn foam | Excellent life (6+ years)<br>Ultra light (4 lbs 3SG)<br>No fabrication | R&D for custom colors |
| Surlyn foam with filn. | Long life (5 years)<br>Ultra light (4 lbs 3SG)<br>Easy to build and install | Limited competition |

the skin when acrylic sheeting is cut, and reported cases of acrylic sheeting becoming brittle and shattering at low temperatures. This last problem is supposedly not a problem with LumaSite which is claimed to be shatterproof.

7.3.3 Aluminum with film. Aluminum and elastromeric film are both standard sign materials. As a dayboard system, aluminum with film has been tested on a number of occasions by the Coast Guard. The original "Five-Year Dayboard Project" for example began in 1983 as "The Aluminum Dayboard Project". In 1985, 185 aluminum dayboards with fluorescent film were constructed by Federal Prison Industries and deployed for field tests as part of the Dayboard Improvement Project and Articulated Beacon Project. Results of these tests seem to validate the fact that aluminum as a backing poses no problems with implementation of dayboards in the field. When covered with non-fluorescent film, tne aluminum dayboard's life is determined by the fading of the film. For the Fasign test film, life is estimated at 5 years. It may be possible to recycle the aluminum so it can last ten years as a backing material. Adhesion is not expected to be a problem if the aluminum is properly prepared and the film is correctly applied.

On the negative side, aluminum has several drawbacks. Foremost is the possibility of generating hazardous wastes when degreasing aluminum initially or when refurbishing the dayboard for a second use. Next is the unstable price history of aluminum. Availability of 5052 aluminum required for marine use cannot be guaranteed by the manufacturer. Shipping costs can be significant depending on the mode of transportation and quantity. Deburring of aluminum after cutting and rounding of the corners (recommended safety precautions) add extra steps (and costs) to the manufacturing of dayboards. Theft of aluminum dayboards is expected to be a problem in some districts. For example, in the CGD7 test, ANT St. Petersburg personnel are installing aluminum test dayboards over existing plywood boards to discourage would be vandals from stealing the aluminum dayboards. The green elastromeric film, as previously explained, is not an "IALA" color.

7.3.4 Aluminum with paint. Aluminum with a polyurethane or epoxy paint system is expected to have a life of 6 years in the marine environment. Advantages of using aluminum as the backing are identical to those discussed above: it's been previously field tested, it's relatively lightweight, it's long lasting, and adhesion is not anticipated to be a problem. The additional advantage of using paints is the possibility of a wider range of optimum dayboard colors. The disadvantages of aluminum are also the same as above: it must be properly prepared, costs are high and people would steal painted aluminum dayboards as readily as aluminum dayboards with film. An additional possible disadvantage in painting dayboards is the high Volatile Organic Compounds o:

paints. Special hooded spray booths would probably be required to meet EPA and OSHA regulations for painting metal surfaces. Centralizing production of dayboards or contracting out the entire operation are two options which may minimize the problems of painting dayboards. Another concern of painting dayboards is that the performance of the paint depends heavily on a number of factors including the specific formulation of the paint, the preparation of the backing, the skill of the operator applying the paint, and the ambient temperature. Or in other words: more things can go wrong with paints than with films.

7.3.5 Fiberboard with film. Fiberboard in particular "medex", is relatively inexpensive and with proper protection may last five years as a dayboard. Highway signs using "medex" as a backing and film as the substrate have been reported to last six years in an outdoor environment. The surface of "medex" is excellent for applying films so adhesion should not be a problem. Using "medex" and film to construct dayboards would have minimum impact on the way the Coast Guard presently builds dayboards. One disadvantage of fiberboard with film is that "medex" – while advertised as the first waterproof medium desity fiberboard – requires edge sealing and painting of the backside to survive a minimum of five years. Another concern is that the performance of the fiberboard in a marine environment has not been tested. Finally, the green Fasign film does not meet IALA recommendations.

7.3.6 Fiberboard with paint. The main advantage of painting fiberboard dayboards is the range of colors available to test. The surface of "medex" is also excellent for paints. The fiberboard can be purchased with a 1.5 mil primer applied to all sides. This would reduce the number of paint coats Coast Guard personnel would need to apply. Disadvantages include the fact that the back of the dayboard would need to be painted with a protective coating and the high VOC associated with paints.

7.3.7 Fiberglass reinforced plastic with film. FRP with film offers the following advantages as a dayboard system: long life (5 years), easy fabrication, lightweight (3SG weighs 9 lbs), no environmental concerns, and reasonable cost. FRP with film dayboards are currently being tested in CGD7 by ANT St. Petersburg and ANT Miami. An FRP with film dayboard – deployed in Miami harbor in May 1985 – is still on station. This supports the manufacturer's claim that FRP as a backing material will not rot, peel, or delaminate. As a dayboard material, FRP can be purchased precut to appropriate dayboard sizes. This would eliminate a labor intensive step (cutting dayboards) in the dayboard manufacturing process.

Disadvantages of FRP with film dayboards are the possibility of the dayboard shattering when struck by a vessel and the green Fasign film not being in the recommended IALA color space for aids-to-navigation signals.

7.3.8 Fiberglass reinforced plastic with paint. FRP can also be painted. Advantages of FRP as a backing are identical to those if film is used. The advantage of paint over film is that a wider range of colors and perhaps a slightly longer life may be possible. Disadvantages are that the dayboard would still shatter if struck by a vessel and the environmental concerns associated with painting dayboards. Centralizing dayboard production or contracting out for dayboards may minimize the problems of painting FRP.

7.3.9 Marine grade plywood with film. This system would be no different from the present system except longer life materials – marine grade plywood and non-fluorescent film – would be used to build dayboards. The advantage of this approach is that it would be the easiest system to implement using present Coast Guard methods of building dayboards. Marine grade plywood with Fasign film is being tested extensively in the CGD7 field test of new dayboards. The disadvantage of marine grade plywood is that is is only made from Douglas Fir grown in certain western states or Western larch and is at times difficult to obtain.

7.3.10 Marine grade plywood with paint. Plywood can also be painted. The advantage of painting plywood is perhaps a wider range of custom colors and perhaps extended life over plywood with film dayboards. The disadvantage is a more involved construction process and the environmental concerns associated with paints. Centralized production or contracting out are options to consider with painted dayboards.

7.3.11 100% solids polyurethane dayboards. This system would use a very cheap backing (particle board) completely sealed with 40 mils of properly pigmented 100% solids polyurethane. Such a dayboard would provide the color advantage of paint but without the VOC problem. (VOC of 100% solids polyurethane is 0.0 lbs/gal.). One product evaluated as a potential dayboard substrate material – Instant-set – has an additional advantage of having been specifically formulated for the marine environment. Expected life is excellent – 6+ years. One temporary disadvantage of this approach is the requirement for additional R&D funds to formulate and test custom dayboard colors. Another possible disadvantage is the cost of special equipment and training to construct dayboards. These costs may be reduced by centrally constructing dayboards or contracting out the entire operation.

7.3.12 Surlyn foam. Surlyn foam dayboards would consist of Surlyn foam as the backing and pigmented Surlyn resins as a "topcoat" permanently heat-sealed to the foam. These dayboards would be ultra-light (4 lbs for a 3SG), impact resistant, easy to handle and install, and would combine backing and substrate. Estimated life is excellent – 6+ years. Surlyn foam dayboards would need to be procured direct from the manufacturer – ready for installation – minus the retro reflective number. A temporary disadvantage of Surlyn foam dayboards is that additional R&D funds would be required to optimize custom dayboard colors.

7.3.13 Surlyn foam with film. In this dayboard system, the Surlyn foam serves as the backing and elastromeric vinyl film as the substrate. These dayboards would be ultra-light, easy to handle and install, and could be manufactured by Coast Guard dayboard personnel. Surlyn foam is heat resistant and could be safely used in Coast Guard heat-vacuum applicators. Adhesion of the film to the foam is expected to be excellent. Estimated life of Surlyn foam dayboards with film is 5 years.

7.4 Rating of dayboard systems. Table XI rates each dayboard system discussed in this report as "Fully Acceptable", "Marginally Acceptable", or "Unacceptable". The definitions of these ratings are identical to those used to rate dayboard components in Sections 4.3 and 5.3.

Important assumptions in rating dayboard systems include:

- All systems can be constructed safely with proper precautions.
- All systems can be installed in the field without difficulty.
- Optimum dayboard colors can be formulated for each system.
- The major advantages and disadvantages of each system are not a function of the production method. (Contracting out vs. centralized production vs. present method).
- Adhesion is not a problem for any dayboard system.

Table XI Rating of Dayboard Systems

| System | Rating |
|---|---|
| A/C plywood with fluorescent film | Unacceptable |
| Acrylic sheeting | Marginally acceptable |
| Aluminum with film | Fully acceptable |
| Aluminum with paint | Fully acceptable |
| Fiberboard with film | Marginally acceptable |
| Fiberboard with paint | Marginally acceptable |
| Fiberglass reinforced plastic with film | Fully acceptable |
| Fiberglass reinforced plastic with paint | Fully acceptable |
| Marine plywood with film | Fully acceptable |
| Marine plywood with paint | Fully acceptable |
| 100% solids polyurethane | Marginally acceptable |
| Surlyn foam | Marginally acceptable |
| Surlyn foam with film | Fully acceptable |

## 8.0 RESULTS AND DISCUSSIONS.

Thirteen dayboard systems, including the present system, are discussed and analyzed in this report. Based upon an evaluation of the advantages and disadvantages of each system, the following observations are made:

- The present system is expensive to maintain, is a drain on Coast Guard resources, and may be over designed.

- A five year dayboard would reduce servicing requirements for Coast Guard dayboard personnel and would therefore lower the life cycle costs of supporting the Coast Guard's dayboard system.

- It is possible to construct a long life dayboard (estimated life of 5 years) using existing materials as substrates and backings.

- Assuming new dayboard systems must provide detection and recognition distances at least as good as one year weathered film, then there are no "red" non-fluorescent colors commercially available to construct triangular dayboards. If orange or red-orange colors are allowed, then colors can be formulated to build "red" Coast Guard dayboards.

- The detection and recognition distances of proposed dayboard systems can not be accurately estimated prior to selecting substrates for further testing. For this reason, all substrates with apparently acceptable dayboard colors should be tested in Task E (accelerated weathering) of this project.

- Elastromeric vinyl film is being extensively tested by Coast Guard Headquarter personnel in a field demonstration in the Seventh Coast Guard District. The 5-Year Dayboard Project should take maximum opportunity of this test to gain additional information on the performance of competing dayboard systems. Specifically, dayboard systems which use film as a substrate, should be evaluated by CGD7 as part of their testing program.

- The elastromeric film being tested by Coast Guard Headquarters should be subjected to the same accelerated weathering tests as the other substrates chosen for further testing. Weathered samples should be used to establish the detection and recognition distances of the film.

- Systems requiring paints with high VOCs may exceed EPA or OSHA standards. These standards are not well defined nor understood by industry or government personnel. The use of paints on dayboards should be considered if and only if other dayboard system options (films, acrylics, foam) cannot meet the requirements for dayboard color. Promising paints identified in this phase of the project can still be tested for colorfastness and included in the test of detection and recognition distances. Doing so will document the data for future reference when paints which meet EPA standards may be available.

- The technical benefits of proposed dayboard systems do not depend strongly on whether dayboards are built by Coast Guard personnel or by contractors. This observation is supported by the analysis in Appendix D. Some cost savings may be possible if dayboard production is centralized or contracted out entirely to industry.

Cost savings of alternate production techniques are beyond the scope of this report. They are, however, being investigated by Coast Guard Headquarter personnel as part of the Coast Guard's A-76 program.

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## APPENDIX A

## EVOLUTION OF THE COAST GUARD DAYBOARD SYSTEM

Pre - 1962 — **Sparse Information** available on dayboard design. Dayboards were probably constructed locally with few restrictions on color or materials. (See attached figure).

July 1961 to May 1964 — Tests conducted by the Coast Guard Field Testing and Development Unit at Curtis Bay, MD on dayboard materials. Began at **test of fluorescent films and paints.** Expanded in 1963 to include non-fluorescent materials

Aug 1967 — **COMDTINST 10500.10B** issued. Subject: **"Standardization of Daymarks"**. This instruction:

- Directed that fluorescent red-orange film be used on starboard dayboards (triangles).
- Allowed white or black square dayboards depending on background.
- Allowed high density, overlaid B-B plywood (HDOP), 6061-T6 aluminum alloy, or galvanized steel as backing materials.
- Replaced use of pre-colored HDOP with a system using 3M films on uncolored HDOP.

Apr 1968 — Memo from Chief, Aids to Navigation Division (G-EOE) to Chief, Civil Engineering Division (G-ECV) requested permission to begin **green fluorescent dayboard tests.**

Jun 1970 to Dec 1971 — **Daymark Evaluation Program** established by G-EOE to evaluate dayboard materials. Scope: Study included size, shape, and color of dayboards; engineering problems of dayboard materials (substrates, backings, and adhesives); visibility of dayboards (detection/recognition distances). Major results of study: **Adoption of A/C exterior plywood as standard backing material;** continued interest in development fluorescent films.

## EVOLUTION OF THE COAST GUARD DAYBOARD SYSTEM (CONTINUED)

| | |
|---|---|
| Feb 1972 | Program manager for aids-to-navigation (G-WAN) and ocean engineering branch (G-EOE-4) agreed to design an all fluorescent dayboard system. |
| Apr 1973 | **Project Management Plan** written by G-EOE-4 personnel. Two goals: One, devise a standardized dayboard system that is effective visually, is cost effective, and if possible, conforms to international agreements. Two, resolve problem areas remaining from Daymark Evaluation Study. Plan **laid groundwork** for the Coast Guard to work with 3M **to develop the present dayboard system** using plywood and fluorescent films. |
| Apr 1973 to Jan 1981 | Status quo for dayboards. Term contracts issued annually to 3M for films. Dayboards replaced as fading occurred, approximately every 2 years. |
| Jan 1981 to Jan 1983 | Interest in competitive procurements led to two year **Qualified Products List testing** of 432 one-foot square dayboards from 4 manufacturers **of fluorescent films**. Results reported by Winslow and Stachon, USCG R&D Center Report 1983. Results estimated useful life of "improved" fluorescent films at 3-4 years. |
| Oct 1984 | **Dayboard Material Study: Visibility and Material Degradation.** USCG R&D Center Letter Report by Mandler and Scoffone. Measured detection and recognition distances of weathered and unweathered fluorescent films. Data indicated fluorescent film recognition ranges became unacceptable after two years exposure. |
| Jan 1985 to Jan 1987 | **Dayboard Improvement Project** established by G-EOE. Focussed on selection of suitable backing material for a "5-Year Dayboard". 100 prototype dayboards (half aluminum, half fiber-glass reinforced plastic (FRP) deployed for operational tests. Final report not issued. |
| Aug 1987 | **Detection and Identification of Florescent and Non-fluorescent Daymark Materials.** USCG R&D Center Report 14/87 by Mandler. Identified promising non-fluorescent materials for use in daytime signaling. |

## EVOLUTION OF THE COAST GUARD DAYBOARD SYSTEM (CONTINUED)

Aug 1988 **Alternatives for Extending the Lifetime of Dayboards.** CG R&D Center letter report by Mandler and Wroblewski. Examined options to extend dayboard life. **Recommended development of a 5-year dayboard.**

Aug 1989 Contract awarded to Analysis and Technology, Inc. to provide technical and engineering support to design, build, and test a 5-year dayboard.

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# APPENDIX B
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# APPENDIX C

# PRODUCING COLORS FOR COAST GUARD NAVIGATIONAL SIGNS

## SIGN MATERIAL

The sign material for "dayboard" signs should have the following characteristics:

It should itself be stable for well over 5 years when exposed at a South Florida test site. It should not become brittle, craze, lose gloss, develop haze, or change color.

It should be compatible with the colorants that will be used to make the desired red and green colors, and should provide a benign environment for these colorants. It should not, for instance, contain residual free radicals or other reactive components that would shorten the life of the colorants.

If possible, it should actually protect the colorants. It might, for example, include an ultraviolet absorber or an antioxidant.

Since the colors are to have a maximum reflectance for their chromaticity, the materials in their uncolored state should be water clear or, possibly, non-absorbing white. A material that is itself yellow, brown, or gray will never produce the desired bright red and green colors.

Possible candidates for dayboard materials would seem to include:

- The hard glossy paints based on epoxy or urethane.
- Acrylic polymer in either sheets or thin film.
- Surlyn foam, as discussed below.
- Tenite butyrate (Uvex) in extruded sheet form.
- Polycarbonate in extruded sheet form.

All these materials would be compatible with the appropriate colorants required to make the red and green colors.

I do not have a great deal of experience with paint formulation, but I believe paints could be produced that would retain a serviceable color for 5 years.

Polycarbonate offers good initial impact resistance, but is expensive and does not weather particularly well. I do not believe it is a prime candidate.

Surlyn as sold by DuPont is not considered by them to be suitable for 5 year outdoor exposure. However, DuPont believes that a package of additives can be put into Surlyn that will make it hold up for 5 years. I understand you have found that Softlite, made from Surlyn, may be a satisfactory material.

Uvex is manufactured by Eastman Chemical and extruded into sheet by Gemini Manufacturing. (They call it Gemex.) It probably does not retain gloss as well as acrylic, but it should be serviceable for 5 years. Gemini can be contacted at (800) 538-8377. However, Gemini does not do color matches. It takes an order of 2000 pounds to get a color matched by Eastman.

Cast acrylic sheet is extremely weatherable, and should remain serviceable for well over 5 years. One source of supply is Glasflex (201) 647-4103.

Extruded acrylic sheet should also easily hold up for 5 years. It is produced my a number of extruders, but they tend to make long runs and often use pre-colored material. It may be hard to find one that is interested in this project.

Acrylic polymer can also be extruded into thin film. I believe the Coburn Corporation, (201) 367-5501, could produce the desired colors and have them hold up for over 5 years.

With respect to all the above materials, I would like to emphasize that weathering performance is hard to predict and dangerous to generalize about. Surlyn is an example of a material that is not satisfactory in its original form, but that may be satisfactory with the proper additive package. Other materials that you would expect to hold up well might not last 5 years if the colorants, the additives, and the manufacturing procedures are not all correct and well controlled. I believe the qualification list of materials must be on a very specific "brand name" basis and not just a list of generic materials.

## RED COLORANTS

## RED COLORANTS

Probably the most stable red pigments are the well known inorganic cadmium pigments. However, these pigments are not bright enough to achieve the desired reflectance for a given chromaticity. It will be necessary to use organic red pigments or possibly organic red dyes (or both in combination). Titanium dioxide pigment (Ti02) might also be added to the formulation if increased opacity is needed. Red organic pigments are sold by such companies as Ciba-Geigy and American Hoechst. Red organic dyes are sold by Atlantic Chemical, BASF, Morton Chemical, and others. Ti02 is sold by DuPont and others. The manufacturer of the colored material should contact these suppliers directly and integrate their recommendations with his own experience and expertise. Pigment red 254 is an example of a red organic pigment that may be suitable. If organic dyes are used, they should probably be of the anthraquinone type, such as solvent red 135. Dyes are generally not considered to give the weathering performance of pigments. They can, however, give good results if formulated correctly, as evidenced by automobile red tail lights which use dyes and which last forever.

## GREEN COLORANTS

The phthalocyanine green pigments give a bright green color and weather very well. They are widely used and should be familiar to any producer of colored material. Phthalo pigments are so finely divided that they are transparent, so Ti02 would be needed to provide opacity. The desired green color may be more yellow than can be produced by phthalo pigments alone. In that case, they can be shaded with one of the stable yellow dyes, such as the anthraquinone types.

## BEST POSSIBLE REFLECTANCE

The best theoretical reflectance for a given chromaticity can be calculated from optimum curves of reflectance versus wavelength. These curves make an abrupt transition from zero reflectance at the undesired wavelengths to maximum reflectance at the desired wavelengths. Curves for real colorants have slopes that are not as steep, and have maximum values that are not as high. Maximum reflectance values for any chromaticity are contained in reference (2). I used computer simulations with slightly more realistic assumptions to modify the values from reference (2). For instance, I assumed that even in theory the reflectance at a given wavelength will not exceed 90%. The resultant values are listed below. Data is by CIE source C. I believe the tables cover the chromaticity areas of primary interest, but I can run additional data points on request.

| RED | | | GREEN | | |
|---|---|---|---|---|---|
| x | y | MAXIMUM REFLECT | x | y | MAXIMUM REFLECT |
| .680 | .300 | 11% | .240 | .400 | 71% |
| .670 | .310 | 14% | .240 | .450 | 68% |
| .660 | .320 | 17% | .240 | .500 | 65% |
| .650 | .330 | 20% | .300 | .450 | 79% |
| .640 | .340 | 23% | .300 | .500 | 76% |
| .600 | .320 | 25% | .320 | .450 | 82% |
| .600 | .330 | 27% | .320 | .500 | 77% |
| .600 | .340 | 29% | .351 | .594 | 72% |
| .627 | .333 | 23% | | | |
| .572 | .405 | 41% | | | |

**BEST PRACTICAL REFLECTANCE**

Predicting the best reflectance that can be achieved at a given chromaticity in actual practice is difficult without making up some real test samples. If a manufacturer can produce a sample with a given percentage of the maximum at one chromaticity point, he can probably hold that same percentage as he moves from point to point in that color area.

I believe red sign material can be produced with about 75% of the theoretical maximum reflectance values.

For the green sign material, I believe about 60% of the maximum reflectance values can be achieved.

Ronald E Bostick

Ronald E. Bostick 2/14/90

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2. THE SCIENCE OF COLOR, published by the OPTICAL SOCIETY OF AMERICA, is a basic text on color which includes a graphical representation of the maximum possible reflectance values (figure 86, page 310).

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APPENDIX D
TECHNICAL EVALUATION OF DAYBOARD SYSTEMS
USING EXPERT CHOICE

## 1.0 INTRODUCTION.

This appendix evaluates the technical benefits of dayboard systems using a decision support computer aid called Expert Choice. Expert Choice is an analytical tool which assists the user to model a problem, compare alternative solutions, and perform "What If?" analyses. Advantages and limitations of Expert Choice are discussed and the decision process explained. Several Expert Choice models using different evaluation criteria are constructed and used to determine the technical benefits of proposed dayboard systems. This approach provides the maximum amount of information needed to rank order dayboard systems based on technical merit.

## 2.0 EXPLANATION OF EXPERT CHOICE.

Because Expert Choice is used extensively in this analysis, this section discusses the advantages and limitations of Expert Choice.

Advantages of Expert Choice are summarized in the following quote from the user's manual:

> "Expert Choice is an expert support system, and as such does not make decisions, but facilitates decision making. It does so by helping you:
>
> - organize complexity
> - incorporate quantitative information as well as knowledge and intuition based on years of experience,
> - consider tradeoffs among competing criteria,
> - synthesize to determine the best alternatives, and
> - communicate the rationale for a decision to others."

All of these attributes of Expert Choice are important for analyzing dayboard systems. The first and last advantages are particularly relevant to the dayboard project. One reason Expert Choice was chosen to evaluate dayboard systems is the ability of the program to organize and present a large amount of technical data gathered on dayboard materials. Others reasons include

the short amount of time required to become proficient in using Expert Choice (less than one hour) and the need for an "objective tool to analyze subjective data."

Limitations of Expert Choice are grouped into two areas: technical limitations and "perceived" weaknesses. Technically, Expert Choice limits the number of sub-criteria for any one goal to seven. For the dayboard analysis this means that it isn't possible using Expert Choice to set a goal of "Select the best dayboard" and then have more than seven criteria. Under "perceived" weakness, it can be argued that any computer decision aid can be biased by the programmer to selectively alter the outcome of an analysis. Expert Choice guards against bias inherent in any decision by forcing the user to logically construct a model and be consistent in making judgments with regards to the relative importance of evaluation criteria. A detailed explanation of how Expert Choice does this is included in the user's manual. The key point is that while Expert Choice is not "bias-proof", the emphasis is on the user - not the computer - making decisions. The next section discusses the mechanics of the Expert Choice decision process.

## 3.0 EXPERT CHOICE DECISION PROCESS (as related to dayboard systems).

Expert Choice uses a seven step decision process based on work explained by Herbert Simon, nobel laureate, in the book "The New Science of Management Decision." The seven steps are:

Step 1: Define and research the problem.
Step 2: Elimate infeasible alternatives.
Step 3: Structure an Expert Choice model.
Step 4: Make judgments.
Step 5: Synthesize.
Step 6: Examine and verify decision.
Step 7: Document the decision.

3.1 Define and research the problem. This step requires three sub-tasks: identify the problem, identify criteria and alternatives, and research alternatives. The problem to be solved is to rank order potential dayboard systems based on technical merit. Criteria to evaluate dayboard systems is subjective. Three different sets of criteria are used in this analysis. One includes the broad categories of: "Handling", "Durability", and "Environmental." Another set of criteria includes: "Estimated life in a marine environment," "Ease of constructing and installing the dayboard," "Safety considerations," and "Signal Effectiveness." The third set of criteria consists of: "Ease of

construction," "Ease of installation," "Personnel safety," "Environmental Safety," "Signal Effectiveness," and "Availability."

Once criteria are agreed upon, the next steps are to identify and research alternatives which could possibly meet the criteria. For dayboards, fifteen systems (including the present system) were chosen for evaluation based on literature searches, analysis of manufacturers' technical data, market surveys, and past test experience with dayboard materials.

3.2 Eliminate infeasible alternatives. This step identifies which of the evaluation criteria are "Must" objectives. Alternatives which do not meet "Must" objectives can be eliminated from further analysis at this step. For dayboards, "Must" criteria would include: "Be able to survive a minimum of five years in a marine environment," "Not present an unacceptable safety hazard to personnel or the environment," "Have detection and recognition distances at least equal to the detection and recognition distances of one-year weathered fluorescent film," and "Not be so heavy as to make it difficult to mount the dayboard on existing Coast Guard structures."

The first of these "Must" criteria is not an absolute requirement of the dayboard project, but rather is a goal established for the life time of new dayboards. However, under this criterion, fabrics were eliminated as potential dayboard materials. Fluorescent film, with a two year service life, is evaluated to document the performance of the present dayboard system.

The last of the "Must" criteria is used to eliminate galvanized steel with paint and galvanized steel with film as possible dayboard systems. The weight of a 3SG galvanized steel dayboard (14 gauge, .0785 inches thick) is 30 pounds, twice the weight of present wooden dayboards.

3.3 Structure an Expert Choice model. Step 3 is to construct the Expert Choice model using the criteria and alternatives identified in previous steps. The form of the model can vary, as will be seen in section 4.0 which presents three possible models for dayboard systems. An important point is that there is no one "correct" model for a decision. As pointed out in the Expert Choice manual:

"Individuals informed about a particular problem may structure it hierarchically somewhat different, but if their judgments are similar, their overall answers tend to be similar. The process is robust. In other words, fine distinctions within the hierarchy tend in practice not to be decisive."

For important decisions, Expert Choice models can be constructed with alternate views. These additional models can be used to answer the "What If?" questions such as "What If Handling" is twice as important as "Safety" and "Durability?"

3.4 Make judgments. In Expert Choice, judgments are grouped into two types: judgments which compare the relative importance of evaluation criteria and judgments which rate each dayboard system against specific criteria. The relative importance of criteria is the more subjective judgment. Using a pairwise comparison technique, evaluation criteria are judged as to what extent one criterion is better than another. When all comparisons are completed, Expert Choice calculates a consistency ratio which is an indication of the quality of the model. For example, an inconsistency ratio of 0.10 or greater indicates judgments made were inconsistent and should be reevaluated.

Judgments for the dayboard models are the author's judgments based on: a review of manufacturers' technical literature; analysis of any available test data for the dayboard systems - in particular results of actual field tests; and discussions with Coast Guard dayboard personnel, technical experts in the field of color science, and industrial technical representatives. Final judgments for dayboard systems will be based on a group consensus which will take into account the results of Coast Guard field tests of prototype dayboard systems.

3.5 Synthesize the model. This is the step where Expert Choice calculates the total score for each alternative. The alternatives with the highest scores are the "best" alternatives according to the criteria used in the model. A capability of Expert Choice is to present either total scores or normalized scores expressed as a number between 0 and 1 or as a percentage between 0% - 100%. For the dayboard systems, scores are reported as total scores as the objective of rank ordering dayboard systems is independent of how scores are reported.

3.6 Examine and verify decision. After calculating scores for each alternative, the next logical question to ask is "Do they make sense?". For example, if low weight is a primary factor in selecting the best dayboard systems, and the top alternatives calculated by Expert Choice are the heaviest dayboards, then the Expert Choice model may need to be reexamined.

With any decision, decision makers often have their bias about which alternative is "best" based on their intuition and experience. For dayboard systems this bias may include "Paint is best because buoys are painted", "Foam is best because it's been tested", and so on. The beauty of

Expert Choice is that it allows decision makers to apply their experience, insights, and intuition in a logical and thorough way within the framework of the Expert Choice model.

The Expert Choice model is not "casted in bronze." Judgments, criteria, and the structure itself may be modified to reflect new information or add new criteria. Even after determining the best alternatives based on total scores, if there is still doubt about the decision, additional Expert Choice models can be constructed with "alternative views" of the problem. This is the case for evaluating dayboard systems, as four models are presented - each representing a different perspective on how "best" to analyze the benefits of competing dayboard systems.

3.7 Document the decision. The final step in Expert Choice is documenting the decision. This is necessary to justify the decision to others and to establish a basis for evaluating the decision in the future. This is particularly important for selecting dayboard systems. The criteria used - and the judgments made to choose dayboard systems for possible implementation throughout the Coast Guard - must be clearly explained. Expert Choice is a method to present a large amount of information in an organized manner.

## 4.0 EXPERT CHOICE MODELS FOR TECHNICAL BENEFITS OF DAYBOARD SYSTEMS.

Four Expert Choice models are presented in this section. Each one approaches the problem of determining the technical benefits of competing dayboard systems from a different perspective. Overviews of each model are included in this section; additional details of the models are presented in section 7.0.

4.1 Model A1 - Handling (20%), Durability (40%), Environmental (40%). This model focuses on three features of dayboard systems:

How easy are they to assemble and install?

How do they perform under normal and severe weather conditions?

How safe are the dayboards for Coast Guard personnel and the environment?

Weathering and safety factors are judged to be equal to each other and both are twice as important as the ease of handling. Figure 4-1 is an overview of the model.

4.2 Model A2 - Handling (50%), Durability (25%), Environmental (25%). Criteria of this model are identical to the criteria in Model A1. However, the weighting of criteria in this model favors the ease of handling dayboards as opposed to the performance of the dayboard in a marine

environment and safety considerations. The single most important criterion is the weight of the dayboard. Figure 4-2 presents the model.

4.3 Model B - Systems Engineering Model. This model attempts to evaluate dayboard system benefits by analyzing five important questions concerning a new dayboard system. These are:

Will it survive in a marine environment?

Is it easy for dayboard shop personnel to build?

Is it easy for field personnel to install and service?

Is it safe to handle and safe for the environment?

Does it meet operational requirements?

These questions cover the entire spectrum of dayboard performance - from assembling raw materials to considering the signal the dayboard presents to the mariner. This model approaches dayboard analysis from a systems engineering perspective. The criteria used for evaluation and the associated weightings are: Estimated life (16.3%), Ease of construction (5.2%), Ease of installation (5.2%), Safety considerations (34.6%), and Signal effectiveness (38.6%). All of these criteria are similar to criteria in Model A1 and A2 except for signal effectiveness.

Signal effectiveness is defined as the measured detection and recognition distance of weathered dayboard materials as compared to the detection and recognition distances of one-year weathered fluorescent film. This quantity will not be determined until after prototype dayboards are tested. Therefore, all candidate dayboard systems are rated as equal for signal effectiveness at this time. Model B may be more appropriate for the final evaluation of dayboard systems - after all testing is completed. Figure 4-3 presents the model.

4.4 Model C - Dayboard benefits (not including estimated life). This model quantifies benefits which then can be used in a standard benefit-to-cost analysis to determine the most cost effective dayboard systems. The reason for omitting estimated life as a benefit is the importance estimated life plays in determining dayboard costs. It was felt that including estimated life as a benefit placed too much emphasis on a single criterion.

The criteria and weights for the model are: Ease of construction (11.1%), Ease of installation (11.1%), Personnel safety (15.9%), Environmental safety (20.8%), Signal effectiveness (36.6%), and Availability of dayboards (4.4%). Figure 4-4 presents the model.

## Figure 4-1 Model A1

```
                 maximize dayboard benefits
                        ____________
                        !  GOAL    !
                        !          !
                        ! L 1.000!
                        ------------
                             !
                 ________________________
                 !           !           !
           ____________ ____________ ____________
           !HANDLING!   !DURABLTY!   !ENVIRMNT!
           !        !   !        !   !        !
           ! L 0.20     ! L 0.400!   ! L 0.400!
           ------------ ------------ ------------
           !-ASSEMBLE   !-WEATHER    !-PRE-INST
           ! L 0.500    ! L 0.359    ! L 0.500
           !-INSTALTN   !-SEVERE     !-POST-INS
           ! L 0.500    ! L 0.641    ! L 0.500
```

```
  GOAL    --- maximize dayboard benefits
ASSEMBLE  --- factors to consider when assembling dayboard
DURABLTY  --- durability - effect of weather on dayboard performance
ENVIRMNT  --- environmental considerations - effect on people and nature
HANDLING  --- ease of handling dayboard materials and/or assembled dayboard
INSTALTN  --- installation of dayboard in field - factors to consider
POST-INS  --- possible dayboard effects on the environment after installation
PRE-INST  --- effect of dayboard on personnel during assmbly and mounting
SEVERE    --- performance during severe weather - storms, flooding, waves
WEATHER   --- performance in normal marine environment

L         --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

## Figure 4-2 Model A2

```
                 maximize dayboard benefits

                        ___________
                        !  GOAL   !
                        !         !
                        ! L 1.000!
                        -----------
                             !
               ______________________________
               !             !              !
          ____________  ____________  ____________
          !HANDLING!   !DURABLTY!    !ENVIRMNT!
          !        !   !        !    !        !
          ! L 0.500!   ! L 0.250!    ! L 0.250!
          -----------  -----------   -----------
          !-ASSEMBLE   !-WEATHER     !-PRE-INST
          ! L 0.500    ! L 0.359     ! L 0.500
          !-INSTALTN   !-SEVERE      !-POST-INS
          ! L 0.500    ! L 0.641     ! L 0.500
```

```
  GOAL    --- maximize dayboard benefits
ASSEMBLE  --- factors to consider when assembling dayboard
DURABLTY  --- durability - effect of weather on dayboard performance
ENVIRMNT  --- environmental considerations - effect on people and nature
HANDLING  --- ease of handling dayboard materials and/or assembled dayboard
INSTALTN  --- installation of dayboard in field - factors to consider
POST-INS  --- possible dayboard effects on the environment after installation
PRE-INST  --- effect of dayboard on personnel during assmbly and mounting
SEVERE    --- performance during severe weather - storms, flooding, waves
WEATHER   --- performance in normal marine environment

L         --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

# Figure 4-3 Model B

| EST LIFE | CONSTRTN | INSTALTN | SAFETY | SIG EFF |
|---|---|---|---|---|
| L 0.162 | L 0.052 | L 0.052 | L 0.346 | L 0.388 |
| -OUTSTAND | -NONE | -EASY | -HARMLESS | -SUPERIOR |
| L 0.367 | L 0.575 | L 0.648 | L 0.471 | L 0.410 |
| -EXCELLNT | -SIMPLE | -AVERAGE | -MINOR | -ABV AVG |
| L 0.270 | L 0.209 | L 0.230 | L 0.273 | L 0.299 |
| -ACCEPTBL | -AVERAGE | -HARD | -AVERAGE | -STANDARD |
| L 0.252 | L 0.117 | L 0.122 | L 0.148 | L 0.169 |
| -MARGINAL | -INVOLVED | | -INDUSTAL | -BLW AVG |
| L 0.088 | L 0.059 | | L 0.079 | L 0.098 |
| -POOR | -COMPLEX | | -HAZARD | -UNSATIS |
| L 0.025 | L 0.040 | | L 0.029 | L 0.024 |

GOAL --- rank order dayboard systems (technical benefits)
ABV AVG --- above average - detection/recognition distance exceeds standard
ACCEPTBL --- acceptable 5 years
AVERAGE --- average - no change from present methods
BLW AVG --- below average - detection/recognition distance less than standard
COMPLEX --- complex - multiple steps to prepare backing and substrate
CONSTRTN --- construction of dayboards (how easy is it to build?)
EASY --- easy - no special tools or mounting brackets required
EST LIFE --- estimated lifetime (how long does it last?)
EXCELLNT --- excellent 6 years
HARD --- hard - more invovled than present system - special tools required
HARMLESS --- harmless - no effect on environment, safe to handle
HAZARD --- hazardous to environement or personnel
INDUSTAL --- industrial standards required
INSTALTN --- installation of dayboards (how easy is it to install?)
INVOLVED --- involved - multiple steps to prepare backing or substrate
MARGINAL --- marginal barely 5 years
MINOR --- minor - safe for environment, physical hazard if dropped
NONE --- none - no fabrication needed
OUTSTAND --- outstanding 7+ years
POOR --- POOR - LESS THAN 5 YEARS
SAFETY --- safety concerns (what's the effect on personnel & environment?)
SIG EFF --- signal effectiveness (does it satisfy operational requirements?)
SIMPLE --- simple - application of retro only
STANDARD --- standard - one year weathered fluorescent film
SUPERIOR --- superior - average distance greatly exceeds standard
UNSATIS --- unsatisfactory - distances less than nominal ranges of dayboards

L --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT

## Figure 4-4 Model C

maximize dayboard benefits

| CONSTRTN | INSTALTN | PERSAFTY | ENVSAFTY | SIG EFF | AVAILBTY |
|---|---|---|---|---|---|
| L 0.111 | L 0.111 | L 0.159 | L 0.208 | L 0.366 | L 0.044 |
| -NONE L 0.355 | -EASY L 0.460 | -HARMLESS L 0.373 | -HARMLESS L 0.438 | -SUPERIOR L 0.315 | -GOOD L 0.485 |
| -SIMPLE L 0.284 | -AVERAGE L 0.319 | -MINOR L 0.301 | -LITTLE L 0.359 | -ABV AVG L 0.315 | -FAIR L 0.343 |
| -AVERAGE L 0.233 | -HARD L 0.221 | -NORMAL L 0.195 | -SOME L 0.167 | -STANDARD L 0.253 | -POOR L 0.120 |
| -INVOLVED L 0.079 | | -INDUSTAL L 0.096 | -HARMFUL L 0.036 | -BLW AVG L 0.092 | -UNSATIS L 0.051 |
| -COMPLEX L 0.050 | | -HAZARD L 0.034 | | -UNSAT L 0.025 | |

```
GOAL      --- maximize dayboard benefits
ABV AVG   --- above average - detection/recognition distance exceeds standard
AVAILBTY  --- are the dayboard materials readily available?
AVERAGE   --- no change from present methods
BLW AVG   --- below average - detection/recognition distance less than standard
COMPLEX   --- multiple steps to prepare backing and substrate
CONSTRTN  --- ease of constructing dayboard
EASY      --- no special tools or mounting brackets required
ENVSAFTY  --- is the dayboard safe for the environment?
FAIR      --- materials usually available on open market
GOOD      --- materials always available on open market
HARD      --- more involved than present system - special tools needed
HARMFUL   --- good chance of dayboard materials harming the environment
HARMLESS  --- safe to handle; no adverse effects on environment
HAZARD    --- past history of materials adversly affecting personnel
INDUSTAL  --- industrial standards required
INSTALTN  --- ease of installing and servicing dayboard
INVOLVED  --- multiple steps to prepare backing or substrate
LITTLE    --- little concern of dayboard materials affecting the environment
MINOR     --- physical hazard if dropped on foot or body
NONE      --- dayboards delivered assembled from manufacturer
NORMAL    --- no problem if proper procedures are followed
PERSAFTY  --- personnel safety - is the dayboard safe to handle
POOR      --- materials may occasional be difficult to obtain
SIG EFF   --- does the dayboard meet opertaional requirements?
SIMPLE    --- precut sign blanks delivered; Coast Guard applies substrate
SOME      --- some concern of dayboard materials affecting the environment
STANDARD  --- detection/recognition distance 1 year weathered fluorescent film
SUPERIOR  --- detection/recognition distance greatly exceeds standard
UNSAT     --- unsatisfactory - distances less than nominal range of dayboards
UNSATIS   --- unsatisfactory - materials often difficult to obtain

L         --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

## 5.0 DISCUSSION OF RESULTS.

The Expert Choice models in the previous section were used to evaluate and rank order 13 potential dayboard systems. Table 5-1 summarizes the results. Judgments used in the analyses are included in the tables in section 7.0.

Two major assumptions affecting the analyses are: (1) dayboards will be constructed by Coast Guard personnel at present dayboard shops; (2) dayboard construction will be contracted out to private industry.

Examining table 5-1, certain dayboard systems consistently rank near the top. These are Surlyn foam, Surlyn foam with film, and FRP with film. Other systems are ranked in the lower half in almost all analyses. These are fiberboard with paint, plywood with paint, and 100% solids polyurethane. Rankings of the remaining dayboard systems depends on the model chosen for analysis.

One interesting observation from table 5-1 is that the ranking of dayboard systems does not appear to be a strong function of whether dayboards are constructed in-house by Coast Guard personnel or contracted out to industry. This observation is made by comparing respective models to each other for in-house vs. contracting-out rankings (A1 to A1, A2 to A2, etc). Some minor changes in the rank order occurs, but there are no large shifts in ranking.

Another interesting observation is that if estimated life is not considered a benefit, and if dayboards are contracted out, the performance of the present dayboard system ranks number 1 in Model C. This is a good example of where experience and intuition must be used in interpreting the results of an Expert Choice analysis. In this case, the present system normally would have been eliminated in step 2 of building the model.

Because weight is a significant factor in Model A2, the top 5 dayboard systems are the dayboards which use foam, FRP, or acrylic as the backing material. Interestingly, when weight is not judged to be as important (Model A1), the same dayboard systems still rank at or near the top.

Figure 5-1. Rank Ordering of Dayboard Systems

| | Coast Guard Production of Dayboards | | | | Contracting Out of Dayboards | | | |
|---|---|---|---|---|---|---|---|---|
| | Expert Choice Models | | | | Expert Choice Models | | | |
| | A1 | A2 | B | C | A1 | A2 | B | C |
| Ranking | | | | | | | | |
| 1 | A | A | A | A | A | A | A | H |
| 2 | B | B | B | B | B | B | C | A |
| 3 | C | E | C | E | C | C | B | B |
| 4 | D | C | E | H | E | E | E | G |
| 5 | E | G | K | I | G | G | G | E |
| 6 | F | K | G | J | D | D | K | L |
| 7 | G | D | J | K | H | F | I | I |
| 8 | H | I | I | C | F | H | J | M |
| 9 | I | H | D | D | I | I | L | J |
| 10 | J | J | H | G | K | K | M | K |
| 11 | K | F | F | L | L | L | H | C |
| 12 | L | L | M | M | J | J | F | F |
| 13 | M | M | L | F | M | M | D | D |

Legend:

A - Surlyn foam
B - Surlyn foam with film
C - Acrylic
D - Aluminum with film
E - FRP with film
F - Aluminum with paint
G - FRP with paint
H - Present system
I - Plywood with film
J - Fiberboard with film
K - Polyurethane 100% solids
L - Plywood with paint
M - Fiberboard with paint

Expert Choice Models - Criteria and Weighting:

A1 - Handling (20%), Durability (40%), Environmental (40%)

A2 - Handling (50%), Durability (25%), Environmental (25%)

B - Estimated Life (16.3%), Ease of Construction (5.2%), Ease of Installation (5.2%), Safety Considerations (34.6%), Signal Effectiveness (38.6%)

C - Ease of Construction (11.1%), Ease of Installation (11.1%), Personnel Safety (15.9%), Environmental Safety (20.8%), Signal Effectiveness (36.6%), Availability of Signs (4.4%)

## 6.0 CONCLUSIONS.

Table 5-1 seems to indicate that the "better" dayboard systems are: Surlyn foam, Surlyn foam with film, acrylic, FRP with film or paint, and aluminum with film or paint. Systems with "less" technical merit include: fiberboard with film or paint, plywood with film or paint, and 100% solids polyurethane.

With the exception of Model C, contracting out of dayboards appears to have little effect on technical merit.

Dayboards which weigh less than present dayboards have "more" technical merit.

Rankings of dayboard systems may change significantly when test results become available on the ability of the dayboard to withstand the effects of a marine environment. The unanswered technical question at this time is the colorfastness of dayboard substrates.

Costs have not been considered in these analyses. Final rank ordering of potential dayboard systems should include both technical benefits and life cycle costs.

## 7.0 DOCUMENTATION OF EXPERT CHOICE ANALYSES.

This section provides additional details of the Expert Choice models used to analyzed dayboard systems. The following tables also document the judgments made for each model.

Figure 7-1 Details of Models A1 and A2

```
              O
  ________________________

  ____________
  HANDLING

   L 0.200
  -----------

  ______________________
  !                    !
  __________  __________
  !ASSEMBLE!  !INSTALTN!
  !        !  !        !
  ! L 0.500!  ! L 0.500!
  ----------  ----------
  !-WEIGHT    !-TRANSPTN
  ! L 0.546   ! L 0.125
  !-CUTTING   !-STORAGE
  ! L 0.132   ! L 0.125
  !-PREPARTN  !-HOISTING
  ! L 0.132   ! L 0.375
  !-APPLICTN  !-MOUNTING
  ! L 0.132   ! L 0.375
  !-REPAIRNG
  ! L 0.058
```

```
APPLICTN --- ease of applying substrate to backing
ASSEMBLE --- factors to consider when assembling dayboard
CUTTING  --- ease of cutting raw material
HANDLING --- ease of handling dayboard materials and/or assembled dayboard
HOISTING --- ease of lifting dayboards while mounting in the field
INSTALTN --- installation of dayboard in field - factors to consider
MOUNTING --- ease of attaching dayboard to ATON structure
PREPARTN --- ease of preparing backing or substrate
REPAIRNG --- ease of repairing dayboards if refurbished
STORAGE  --- ease of storing signs at base or on/board vessel
TRANSPTN --- ease of transporting signs to field units
WEIGHT   --- weight of dayboard ( 3SG)

L        --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

## Figure 7-1 Details of Models A1 and A2 (Continued)

ASSEMBLE

L 0.500

| WEIGHT | CUTTING | PREPARTN | APPLICTN | REPAIRNG |
|---|---|---|---|---|
| L 0.546 | L 0.132 | L 0.132 | L 0.132 | L 0.058 |
| -GREATER | -NONE | -NONE | -NONE | -EASY |
| L 0.072 | L 0.731 | L 0.731 | L 0.731 | L 0.600 |
| -EQUAL | -SAME | -EQUAL | -EQUAL | -MINOR |
| L 0.279 | L 0.188 | L 0.188 | L 0.188 | L 0.200 |
| -LESS | -HARDER | -HARDER | -HARDER | -N/A |
| L 0.649 | L 0.081 | L 0.081 | L 0.081 | L 0.200 |

APPLICTN --- ease of applying substrate to backing
ASSEMBLE --- factors to consider when assembling dayboard
CUTTING --- ease of cutting raw material
EASY --- dayboard can be repaired with minimal effort
EQUAL --- equal to present system
GREATER --- greater than present system
HARDER --- requirements more difficult than present system
LESS --- less than present system
MINOR --- some preparation of backing or substrate
N/A --- not able to refurbish
NONE --- pre-cut blanks or completed signs delivered to Coast Guard
PREPARTN --- ease of preparing backing or substrate
REPAIRNG --- ease of repairing dayboards if refurbished
SAME --- requirements similiar to present system
WEIGHT --- weight of dayboard ( 3SG)

L --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT

Figure 7-1 Details of Models A1 and A2 (Continued)

```
                        ----------
                        INSTALTN
                        !        !
                        ! L 0.500!
                        ----------
                             !
     ------------------------------------------------
     !               !              !               !
 ----------     ----------     ----------     ----------
 !TRANSPTN!     !STORAGE !     !HOISTING!     !MOUNTING!
 !        !     !        !     !        !     !        !
 ! L 0.125!     ! L 0.125!     ! L 0.375!     ! L 0.375!
 ----------     ----------     ----------     ----------
 !-EASIER       !-BETTER       !-SIMPLE       !-EQUAL
 ! L 0.621      ! L 0.731      ! L 0.731      ! L 1.000
 !-EQUAL        !-EQUAL        !-EQUAL
 ! L 0.379      ! L 0.188      ! L 0.188
                !-WORSE        !-INVOLVED
                ! L 0.081      ! L 0.081
```

BETTER --- dayboards require less space than present system
EASIER --- dayboards delivered direct tofield units from manufacturer
EQUAL --- equal to present system
HOISTING --- ease of lifting dayboards while mounting in the field
INSTALTN --- installation of dayboard in field - factors to consider
INVOLVED --- dayboard weighs much more than present dayboards
MOUNTING --- ease of attaching dayboard to ATON structure
SIMPLE --- dayboard weighs less than present dayboards
STORAGE --- ease of storing signs at base or on/board vessel
TRANSPTN --- ease of transporting signs to field units
WORSE --- dayboards require more space than present system

L --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT

## Figure 7-1 Details of Models A1 and A2 (Continued)

```
                C
                !
     ---------------------------
     !          !              !

          ----------
          DURABLTY !

          L [illegible]

                !
          ----------
          !        !
   ----------  ----------
   !WEATHER !  !SEVERE  !
   !        !  !        !
   ! L 0.359!  ! L 0.641!
   ----------  ----------
   !-EXCELLNT  !-SUPERIOR
   ! L 0.369   ! L 0.582
   !-ABV AVG   !-EQUAL
   ! L 0.329   ! L 0.367
   !-AVERAGE   !-UNSATIS
   ! L 0.209   ! L 0.051
   !-BLW AVG
   ! L 0.064
   !-UNSAT
   ! L 0.029
```

```
ABV AVG  --- above average - minor effects of weathering -some fading
AVERAGE  --- barely 5 years service life - noticable fading -time to replace
BLW AVG  --- below average - less than 5 years life - significant color shift
DURABLTY --- durability - effect of weather on dayboard performance
EQUAL    --- equal to present system
EXCELLNT --- 5+ years service life - no rotting of backing or fading of color
SEVERE   --- performance during severe weather - storms, flooding, waves
SUPERIOR --- no visible effect - dayboard remains attached 75MPH winds
UNSAT    --- much less than 5 years - severe color fading
UNSATIS  --- dayboard receives major damage - needs to be replaced
WEATHER  --- performance in normal marine environment

L        --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

Figure 7-1 Details of Models A1 and A2 (Continued)

```
               ENVIRMNT
             L [illegible]
                  !
      ------------------------
      !                      !
 !PRE-INST!           !POST-INS!
 !        !           !        !
 ! L 0.500!           ! L 0.500!
 ----------           ----------
 !-HARMLESS           !-HARMLESS
 ! L 0.555            ! L 0.479
 !-NORMAL             !-LITTLE
 ! L 0.275            ! L 0.302
 !-INDUSTRL           !-SOME
 ! L 0.135            ! L 0.183
 !-HAZARD             !-HARMFUL
 ! L 0.034            ! L 0.036
```

```
ENVIRMNT --- environmental considerations - effect on people and nature
HARMFUL  --- good chance of dayboard materials affecting the environment
HARMLESS --- safe to handle - no adverse effects on people or environment
HAZARD   --- past history of materials adversly affecting personnel
INDUSTRL --- industrial standards required by EPA or OSHA
LITTLE   --- little concern of dayboard materials affecting the environment
NORMAL   --- no problem if proper procedures are followed
POST-INS --- possible dayboard effects on the environment after installation
PRE-INST --- effect of dayboard on personnel during assmbly and mounting
SOME     --- some concern of dayboard materials affecting the environment

L        --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

## Table 7-1 Summary of Judgments and Results for Model A1 (Coast Guard Production of Dayboards)

| ALTERNATIVES | HANDLING ASSEMBLE WEIGHT .0546 | HANDLING ASSEMBLE CUTTING .0132 | HANDLING ASSEMBLE PREPARTN .0132 | HANDLING ASSEMBLE APPLICTN .0132 | HANDLING ASSEMBLE REPAIRNG .0058 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | LESS | NONE | NONE | NONE | N/A |
| 2 SURLYN FOAM/FILM | LESS | NONE | EQUAL | EQUAL | N/A |
| 3 ACRYLIC | LESS | HARDER | NONE | NONE | N/A |
| 4 AL/FILM | EQUAL | HARDER | HARDER | HARDER | MINOR |
| 5 FRP/FILM | LESS | NONE | EQUAL | EQUAL | MINOR |
| 6 AL/PAINT | EQUAL | HARDER | HARDER | HARDER | MINOR |
| 7 FRP/PAINT | LESS | NONE | HARDER | HARDER | MINOR |
| 8 PRESENT SYSTEM | EQUAL | SAME | EQUAL | EQUAL | N/A |
| 9 PLYWOOD/FILM | EQUAL | SAME | EQUAL | EQUAL | N/A |
| 10 POLYURETHANE | EQUAL | NONE | NONE | NONE | MINOR |
| 11 FIBERBOARD/FILM | GREATER | SAME | EQUAL | EQUAL | N/A |
| 12 PLYWOOD/PAINT | EQUAL | SAME | HARDER | HARDER | N/A |
| 13 FIBERBOARD/PAINT | GREATER | SAME | HARDER | HARDER | N/A |

| ALTERNATIVES | HANDLING INSTALTN TRANSPTN .0125 | HANDLING INSTALTN STORAGE .0125 | HANDLING INSTALTN HOISTING .0375 | HANDLING INSTALTN MOUNTING .0375 | DURABLTY WEATHER .1436 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | EQUAL | WORSE | SIMPLE | EQUAL | EXCELLNT |
| 2 SURLYN FOAM/FILM | EQUAL | WORSE | SIMPLE | EQUAL | AVERAGE |
| 3 ACRYLIC | EASIER | BETTER | SIMPLE | EQUAL | EXCELLNT |
| 4 AL/FILM | EQUAL | BETTER | EQUAL | EQUAL | AVERAGE |
| 5 FRP/FILM | EASIER | BETTER | SIMPLE | EQUAL | AVERAGE |
| 6 AL/PAINT | EQUAL | BETTER | EQUAL | EQUAL | ABV AVG |
| 7 FRP/PAINT | EASIER | BETTER | SIMPLE | EQUAL | ABV AVG |
| 8 PRESENT SYSTEM | EQUAL | EQUAL | EQUAL | EQUAL | UNSAT |
| 9 PLYWOOD/FILM | EQUAL | EQUAL | EQUAL | EQUAL | AVERAGE |
| 10 POLYURETHANE | EQUAL | WORSE | EQUAL | EQUAL | EXCELLNT |
| 11 FIBERBOARD/FILM | EQUAL | EQUAL | EQUAL | EQUAL | AVERAGE |
| 12 PLYWOOD/PAINT | EQUAL | EQUAL | EQUAL | EQUAL | ABV AVG |
| 13 FIBERBOARD/PAINT | EQUAL | EQUAL | EQUAL | EQUAL | ABV AVG |

| ALTERNATIVES | DURABLTY SEVERE .2564 | ENVIRMNT PRE-INST .2000 | ENVIRMNT POST-INS .2000 | | TOTAL |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | SUPERIOR | HARMLESS | LITTLE | :: | 0.510 |
| 2 SURLYN FOAM/FILM | SUPERIOR | HARMLESS | LITTLE | :: | 0.472 |
| 3 ACRYLIC | EQUAL | NORMAL | LITTLE | :: | 0.401 |
| 4 AL/FILM | SUPERIOR | NORMAL | LITTLE | :: | 0.373 |
| 5 FRP/FILM | EQUAL | NORMAL | LITTLE | :: | 0.372 |
| 6 AL/PAINT | SUPERIOR | INDUSTRL | SOME | :: | 0.338 |
| 7 FRP/PAINT | EQUAL | INDUSTRL | SOME | :: | 0.335 |
| 8 PRESENT SYSTEM | EQUAL | NORMAL | HARMLESS | :: | 0.325 |
| 9 PLYWOOD/FILM | EQUAL | NORMAL | LITTLE | :: | 0.315 |
| 10 POLYURETHANE | EQUAL | INDUSTRL | SOME | :: | 0.306 |
| 11 FIBERBOARD/FILM | EQUAL | NORMAL | LITTLE | :: | 0.304 |
| 12 PLYWOOD/PAINT | EQUAL | INDUSTRL | SOME | :: | 0.278 |
| 13 FIBERBOARD/PAINT | EQUAL | INDUSTRL | SOME | :: | 0.266 |

## Table 7-2 Summary of Judgments and Results for Model A1 (Contracting Out of Dayboards)

| ALTERNATIVES | HANDLING ASSEMBLE WEIGHT .0546 | HANDLING ASSEMBLE CUTTING .0132 | HANDLING ASSEMBLE PREPARTN .0132 | HANDLING ASSEMBLE APPLICTN .0132 | HANDLING ASSEMBLE REPAIRNG .0058 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | LESS | NONE | NONE | NONE | N/A |
| 2 SURLYN FOAM/FILM | LESS | NONE | NONE | NONE | N/A |
| 3 ACRYLIC | LESS | NONE | NONE | NONE | N/A |
| 4 FRP/FILM | LESS | NONE | NONE | NONE | N/A |
| 5 FRP/PAINT | LESS | NONE | NONE | NONE | N/A |
| 6 PRESENT SYSTEM | EQUAL | NONE | NONE | NONE | N/A |
| 7 AL/FILM | EQUAL | NONE | NONE | NONE | N/A |
| 8 PLYWOOD/FILM | EQUAL | NONE | NONE | NONE | N/A |
| 9 AL/PAINT | EQUAL | NONE | NONE | NONE | N/A |
| 10 POLYURETHANE | EQUAL | NONE | NONE | NONE | N/A |
| 11 PLYWOOD/PAINT | EQUAL | NONE | NONE | NONE | N/A |
| 12 FIBERBOARD/FILM | GREATER | NONE | NONE | NONE | N/A |
| 13 FIBERBOARD/PAINT | GREATER | NONE | NONE | NONE | N/A |

| ALTERNATIVES | HANDLING INSTALTN TRANSPTN .0125 | HANDLING INSTALTN STORAGE .0125 | HANDLING INSTALTN HOISTING .0375 | HANDLING INSTALTN MOUNTING .0375 | DURABLTY WEATHER .1406 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | EASIER | WORSE | SIMPLE | EQUAL | EXCELLNT |
| 2 SURLYN FOAM/FILM | EASIER | WORSE | SIMPLE | EQUAL | AVERAGE |
| 3 ACRYLIC | EASIER | BETTER | SIMPLE | EQUAL | EXCELLNT |
| 4 FRP/FILM | EASIER | BETTER | SIMPLE | EQUAL | AVERAGE |
| 5 FRP/PAINT | EASIER | BETTER | SIMPLE | EQUAL | ABV AVG |
| 6 PRESENT SYSTEM | EQUAL | EQUAL | EQUAL | EQUAL | UNSAT |
| 7 AL/FILM | EQUAL | BETTER | EQUAL | EQUAL | AVERAGE |
| 8 PLYWOOD/FILM | EQUAL | EQUAL | EQUAL | EQUAL | AVERAGE |
| 9 AL/PAINT | EQUAL | BETTER | EQUAL | EQUAL | ABV AVG |
| 10 POLYURETHANE | EQUAL | WORSE | EQUAL | EQUAL | EXCELLNT |
| 11 PLYWOOD/PAINT | EQUAL | EQUAL | EQUAL | EQUAL | ABV AVG |
| 12 FIBERBOARD/FILM | EQUAL | EQUAL | EQUAL | EQUAL | AVERAGE |
| 13 FIBERBOARD/PAINT | EQUAL | EQUAL | EQUAL | EQUAL | ABV AVG |

| ALTERNATIVES | DURABLTY SEVERE .2564 | ENVIRMNT PRE-INST .2000 | ENVIRMNT POST-INS .2000 | | TOTAL |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | SUPERIOR | HARMLESS | LITTLE | :: | 0.513 |
| 2 SURLYN FOAM/FILM | SUPERIOR | HARMLESS | LITTLE | :: | 0.490 |
| 3 ACRYLIC | EQUAL | HARMLESS | LITTLE | :: | 0.466 |
| 4 FRP/FILM | EQUAL | HARMLESS | LITTLE | :: | 0.443 |
| 5 FRP/PAINT | EQUAL | HARMLESS | SOME | :: | 0.436 |
| 6 PRESENT SYSTEM | EQUAL | HARMLESS | HARMLESS | :: | 0.402 |
| 7 AL/FILM | SUPERIOR | NORMAL | LITTLE | :: | 0.398 |
| 8 PLYWOOD/FILM | EQUAL | HARMLESS | LITTLE | :: | 0.392 |
| 9 AL/PAINT | SUPERIOR | NORMAL | SOME | :: | 0.392 |
| 10 POLYURETHANE | EQUAL | HARMLESS | SOME | :: | 0.390 |
| 11 PLYWOOD/PAINT | EQUAL | HARMLESS | SOME | :: | 0.386 |
| 12 FIBERBOARD/FILM | EQUAL | HARMLESS | LITTLE | :: | 0.381 |
| 13 FIBERBOARD/PAINT | EQUAL | HARMLESS | SOME | :: | 0.374 |

Table 7-3 Summary of Judgments and Results for Model A2
(Coast Guard Production of Dayboards)

| ALTERNATIVES | HANDLING ASSEMBLE WEIGHT .1366 | HANDLING ASSEMBLE CUTTING .0330 | HANDLING ASSEMBLE PREPARTN .0330 | HANDLING ASSEMBLE APPLICTN .0330 | HANDLING ASSEMBLE REPAIRNG .0145 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | LESS | NONE | NONE | NONE | N/A |
| 2 SURLYN FOAM/FILM | LESS | NONE | EQUAL | EQUAL | N/A |
| 3 FRP/FILM | LESS | NONE | EQUAL | EQUAL | MINOR |
| 4 ACRYLIC | LESS | HARDER | EQUAL | NONE | N/A |
| 5 FRP/PAINT | LESS | NONE | HARDER | HARDER | MINOR |
| 6 POLYURETHANE | EQUAL | NONE | NONE | NONE | MINOR |
| 7 AL/FILM | EQUAL | HARDER | HARDER | EQUAL | MINOR |
| 8 PLYWOOD/FILM | EQUAL | SAME | EQUAL | EQUAL | N/A |
| 9 PRESENT SYSTEM | EQUAL | SAME | EQUAL | EQUAL | N/A |
| 10 FIBERBOARD/FILM | GREATER | SAME | EQUAL | EQUAL | N/A |
| 11 AL/PAINT | EQUAL | HARDER | HARDER | HARDER | MINOR |
| 12 PLYWOOD/PAINT | EQUAL | SAME | HARDER | HARDER | N/A |
| 13 FIBERBOARD/PAINT | GREATER | SAME | HARDER | HARDER | N/A |

| ALTERNATIVES | HANDLING INSTALTN TRANSPTN .0313 | HANDLING INSTALTN STORAGE .0313 | HANDLING INSTALTN HOISTING .0938 | HANDLING INSTALTN MOUNTING .0938 | DURABLTY WEATHER .0897 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | EASIER | WORSE | SIMPLE | EQUAL | EXCELLNT |
| 2 SURLYN FOAM/FILM | EASIER | WORSE | SIMPLE | EQUAL | AVERAGE |
| 3 FRP/FILM | EASIER | BETTER | SIMPLE | EQUAL | AVERAGE |
| 4 ACRYLIC | EASIER | BETTER | SIMPLE | EQUAL | EXCELLNT |
| 5 FRP/PAINT | EASIER | BETTER | SIMPLE | EQUAL | ABV AVG |
| 6 POLYURETHANE | EQUAL | WORSE | EQUAL | EQUAL | EXCELLNT |
| 7 AL/FILM | EQUAL | BETTER | EQUAL | EQUAL | AVERAGE |
| 8 PLYWOOD/FILM | EQUAL | EQUAL | EQUAL | EQUAL | AVERAGE |
| 9 PRESENT SYSTEM | EQUAL | EQUAL | EQUAL | EQUAL | UNSAT |
| 10 FIBERBOARD/FILM | EQUAL | EQUAL | EQUAL | EQUAL | AVERAGE |
| 11 AL/PAINT | EQUAL | BETTER | EQUAL | EQUAL | ABV AVG |
| 12 PLYWOOD/PAINT | EQUAL | EQUAL | EQUAL | EQUAL | ABV AVG |
| 13 FIBERBOARD/PAINT | EQUAL | EQUAL | EQUAL | EQUAL | ABV AVG |

| ALTERNATIVES | DURABLTY SEVERE .1603 | ENVIRMNT PRE-INST .1250 | ENVIRMNT POST-INS .1250 | | TOTAL |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | SUPERIOR | HARMLESS | LITTLE | :: | 0.581 |
| 2 SURLYN FOAM/FILM | SUPERIOR | HARMLESS | LITTLE | :: | 0.531 |
| 3 FRP/FILM | EQUAL | HARMLESS | LITTLE | :: | 0.517 |
| 4 ACRYLIC | EQUAL | NORMAL | LITTLE | :: | 0.493 |
| 5 FRP/PAINT | EQUAL | INDUSTRL | SOME | :: | 0.454 |
| 6 POLYURETHANE | EQUAL | HARMLESS | SOME | :: | 0.423 |
| 7 AL/FILM | SUPERIOR | NORMAL | HARMLESS | :: | 0.405 |
| 8 PLYWOOD/FILM | EQUAL | HARMLESS | HARMLESS | :: | 0.395 |
| 9 PRESENT SYSTEM | EQUAL | HARMLESS | HARMLESS | :: | 0.379 |
| 10 FIBERBOARD/FILM | EQUAL | HARMLESS | HARMLESS | :: | 0.367 |
| 11 AL/PAINT | SUPERIOR | INDUSTRL | SOME | :: | 0.358 |
| 12 PLYWOOD/PAINT | EQUAL | INDUSTRL | SOME | :: | 0.310 |
| 13 FIBERBOARD/PAINT | EQUAL | INDUSTRL | SOME | :: | 0.281 |

Table 7-4 Summary of Judgments and Results for Model A2 (Contracting Out of Dayboards)

| ALTERNATIVES | HANDLING ASSEMBLE WEIGHT .1366 | HANDLING ASSEMBLE CUTTING .0330 | HANDLING ASSEMBLE PREPARTN .0330 | HANDLING ASSEMBLE APPLICTN .0330 | HANDLING ASSEMBLE REPAIRNG .0145 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | LESS | NONE | NONE | NONE | N/A |
| 2 ACRYLIC | LESS | NONE | NONE | NONE | N/A |
| 3 SURLYN FOAM/FILM | LESS | NONE | NONE | NONE | N/A |
| 4 FRP/FILM | LESS | NONE | NONE | NONE | N/A |
| 5 FRP/PAINT | LESS | NONE | NONE | NONE | N/A |
| 6 AL/FILM | EQUAL | NONE | NONE | NONE | N/A |
| 7 AL/PAINT | EQUAL | NONE | NONE | NONE | N/A |
| 8 PRESENT SYSTEM | EQUAL | NONE | NONE | NONE | N/A |
| 9 PLYWOOD/FILM | EQUAL | NONE | NONE | NONE | N/A |
| 10 POLYURETHANE | EQUAL | NONE | NONE | NONE | N/A |
| 11 PLYWOOD/PAINT | EQUAL | NONE | NONE | NONE | N/A |
| 12 FIBERBOARD/FILM | GREATER | NONE | NONE | NONE | N/A |
| 13 FIBERBOARD/PAINT | GREATER | NONE | NONE | NONE | N/A |

| ALTERNATIVES | HANDLING INSTALTN TRANSPTN .0313 | HANDLING INSTALTN STORAGE .0313 | HANDLING INSTALTN HOISTING .0938 | HANDLING INSTALTN MOUNTING .0938 | DURABLTY WEATHER .0897 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | EASIER | WORSE | SIMPLE | EQUAL | EXCELLNT |
| 2 ACRYLIC | EASIER | BETTER | SIMPLE | EQUAL | EXCELLNT |
| 3 SURLYN FOAM/FILM | EASIER | WORSE | SIMPLE | EQUAL | AVERAGE |
| 4 FRP/FILM | EASIER | BETTER | SIMPLE | EQUAL | AVERAGE |
| 5 FRP/PAINT | EASIER | BETTER | SIMPLE | EQUAL | ABV AVG |
| 6 AL/FILM | EQUAL | BETTER | EQUAL | EQUAL | AVERAGE |
| 7 AL/PAINT | EQUAL | BETTER | EQUAL | EQUAL | ABV AVG |
| PRESENT SYSTEM | EQUAL | EQUAL | EQUAL | EQUAL | UNSAT |
| 9 PLYWOOD/FILM | EQUAL | EQUAL | EQUAL | EQUAL | AVERAGE |
| 10 POLYURETHANE | EQUAL | WORSE | EQUAL | EQUAL | EXCELLNT |
| 11 PLYWOOD/PAINT | EQUAL | EQUAL | EQUAL | EQUAL | ABV AVG |
| 12 FIBERBOARD/FILM | EQUAL | EQUAL | EQUAL | EQUAL | AVERAGE |
| 13 FIBERBOARD/PAINT | EQUAL | EQUAL | EQUAL | EQUAL | ABV AVG |

| ALTERNATIVES | DURABLTY SEVERE .1603 | ENVIRMNT PRE-INST .1250 | ENVIRMNT POST-INS .1250 | | TOTAL |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | SUPERIOR | HARMLESS | LITTLE | :: | 0.581 |
| 2 ACRYLIC | EQUAL | HARMLESS | LITTLE | :: | 0.567 |
| 3 SURLYN FOAM/FILM | SUPERIOR | HARMLESS | LITTLE | :: | 0.567 |
| 4 FRP/FILM | EQUAL | HARMLESS | LITTLE | :: | 0.553 |
| 5 FRP/PAINT | EQUAL | HARMLESS | SOME | :: | 0.549 |
| 6 AL/FILM | SUPERIOR | NORMAL | LITTLE | :: | 0.444 |
| 7 AL/PAINT | SUPERIOR | NORMAL | SOME | :: | 0.439 |
| 8 PRESENT SYSTEM | EQUAL | HARMLESS | HARMLESS | :: | 0.433 |
| 9 PLYWOOD/FILM | EQUAL | HARMLESS | LITTLE | :: | 0.427 |
| 10 POLYURETHANE | EQUAL | HARMLESS | SOME | :: | 0.423 |
| 11 PLYWOOD/PAINT | EQUAL | HARMLESS | SOME | :: | 0.423 |
| 12 FIBERBOARD/FILM | EQUAL | HARMLESS | LITTLE | :: | 0.399 |
| 13 FIBERBOARD/PAINT | EQUAL | HARMLESS | SOME | :: | 0.395 |

Table 7-5 Summary of Judgments and Results for Model B
(Coast Guard Production of Dayboards)

| ALTERNATIVES | EST LIFE .1631 | CONSTRTN .0523 | INSTALTN .0523 | SAFETY .3465 | SIG EFF .3858 | | TOTAL |
|---|---|---|---|---|---|---|---|
| 1 SURYLN FOAM | EXCELLNT | SIMPLE | EASY | MINOR | STANDARD | :: | 0.249 |
| 2 SURLYN FOAM/FILM | ACCEPTBL | SIMPLE | EASY | MINOR | STANDARD | :: | 0.246 |
| 3 ACRYLIC | EXCELLNT | SIMPLE | EASY | AVERAGE | STANDARD | :: | 0.205 |
| 4 FRP/FILM | ACCEPTBL | AVERAGE | EASY | AVERAGE | STANDARD | :: | 0.198 |
| 5 GALV STEEL/FILM | ACCEPTBL | INVOLVED | HARD | AVERAGE | STANDARD | :: | 0.167 |
| 6 POLYURETHANE | ACCEPTBL | SIMPLE | AVERAGE | INDUSTAL | STANDARD | :: | 0.157 |
| 7 FRP/PAINT | ACCEPTBL | INVOLVED | EASY | HAZARD | STANDARD | :: | 0.154 |
| 8 FIBERBOARD/FILM | MARGINAL | AVERAGE | AVERAGE | AVERAGE | STANDARD | :: | 0.149 |
| 9 PLYWOOD/FILM | MARGINAL | AVERAGE | AVERAGE | AVERAGE | STANDARD | :: | 0.149 |
| 10 ALUMINUM/FILM | ACCEPTBL | INVOLVED | HARD | INDUSTAL | STANDARD | :: | 0.143 |
| 11 PRESENT SYSTEM | POOR | AVERAGE | AVERAGE | AVERAGE | STANDARD | :: | 0.139 |
| 12 ALUMINUM/PAINT | EXCELLNT | COMPLEX | HARD | HAZARD | STANDARD | :: | 0.128 |
| 13 GALV STEEL/PAINT | EXCELLNT | COMPLEX | HARD | HAZARD | STANDARD | :: | 0.128 |
| 14 FIBERBOARD/PAINT | MARGINAL | INVOLVED | AVERAGE | HAZARD | STANDARD | :: | 0.105 |
| 15 PLYWOOD/PAINT | MARGINAL | INVOLVED | AVERAGE | HAZARD | STANDARD | :: | 0.105 |

Table 7-6 Summary of Judgments and Results for Model B
(Contracting Out of Dayboards)

| ALTERNATIVES | EST LIFE .1631 | CONSTRTN .0523 | INSTALTN .0523 | SAFETY .3465 | SIG EFF .3858 | | TOTAL |
|---|---|---|---|---|---|---|---|
| 1 SURYLN FOAM | EXCELLNT | NONE | EASY | MINOR | STANDARD | :: | 0.268 |
| 2 ACRYLIC | EXCELLNT | NONE | EASY | MINOR | STANDARD | :: | 0.268 |
| 3 SURLYN FOAM/FILM | ACCEPTBL | NONE | EASY | MINOR | STANDARD | :: | 0.265 |
| 4 FRP/FILM | ACCEPTBL | NONE | EASY | MINOR | STANDARD | :: | 0.265 |
| 5 FRP/PAINT | ACCEPTBL | NONE | EASY | MINOR | STANDARD | :: | 0.265 |
| 6 POLYURETHANE | ACCEPTBL | NONE | AVERAGE | MINOR | STANDARD | :: | 0.243 |
| 7 FIBERBOARD/FILM | MARGINAL | NONE | AVERAGE | MINOR | STANDARD | :: | 0.216 |
| 8 PLYWOOD/FILM | MARGINAL | NONE | AVERAGE | MINOR | STANDARD | :: | 0.216 |
| 9 FIBERBOARD/PAINT | MARGINAL | NONE | AVERAGE | MINOR | STANDARD | :: | 0.216 |
| 10 PLYWOOD/PAINT | MARGINAL | NONE | AVERAGE | MINOR | STANDARD | :: | 0.216 |
| 11 PRESENT SYSTEM | POOR | NONE | AVERAGE | MINOR | STANDARD | :: | 0.206 |
| 12 ALUMINUM/PAINT | EXCELLNT | NONE | HARD | AVERAGE | STANDARD | :: | 0.197 |
| 13 GALV STEEL/PAINT | EXCELLNT | NONE | HARD | AVERAGE | STANDARD | :: | 0.197 |
| 14 GALV STEEL/FILM | ACCEPTBL | NONE | HARD | AVERAGE | STANDARD | :: | 0.194 |
| 15 ALUMINUM/FILM | ACCEPTBL | NONE | HARD | AVERAGE | STANDARD | :: | 0.194 |

Table 7-7 Summary of Judgments and Results for Model C
(Coast Guard Production of Dayboards)

| ALTERNATIVES | CONSTRTN .1110 | INSTALTN .1110 | PERSAFTY .1595 | ENVSAFTY .2084 | SIG EFF .3662 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | NONE | EASY | MINOR | LITTLE | STANDARD |
| 2 SURLYN FOAM/FILM | SIMPLE | EASY | MINOR | LITTLE | STANDARD |
| 3 PRESENT SYSTEM | AVERAGE | EASY | NORMAL | HARMLESS | STANDARD |
| 4 FRP/FILM | SIMPLE | EASY | NORMAL | HARMLESS | STANDARD |
| 5 PLYWOOD/FILM | AVERAGE | AVERAGE | NORMAL | HARMLESS | STANDARD |
| 6 POLYURETHANE | NONE | AVERAGE | MINOR | LITTLE | STANDARD |
| 7 FIBERBOARD/FILM | AVERAGE | AVERAGE | NORMAL | HARMLESS | STANDARD |
| 8 ACRYLIC | SIMPLE | EASY | NORMAL | LITTLE | STANDARD |
| 9 AL/FILM | INVOLVED | HARD | NORMAL | HARMLESS | STANDARD |
| 10 FRP/PAINT | INVOLVED | EASY | INDUSTAL | LITTLE | STANDARD |
| 11 PLYWOOD/PAINT | INVOLVED | AVERAGE | INDUSTAL | LITTLE | STANDARD |
| 12 FIBERBOARD/PAINT | INVOLVED | AVERAGE | INDUSTAL | LITTLE | STANDARD |
| 13 AL/PAINT | COMPLEX | HARD | INDUSTAL | LITTLE | STANDARD |

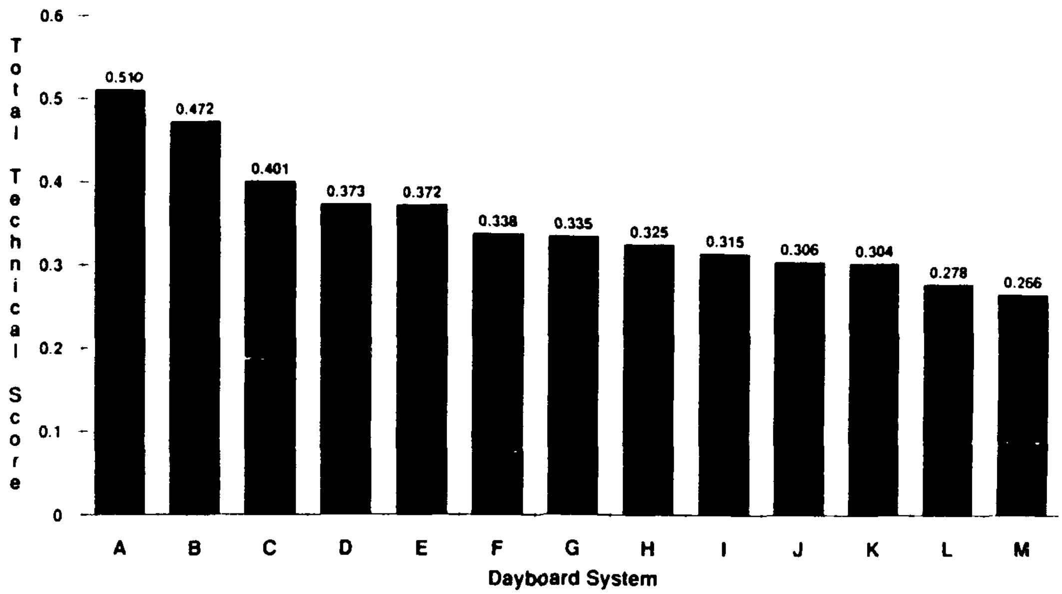
| ALTERNATIVES | AVAILBTY .0441 | | TOTAL |
|---|---|---|---|
| 1 SURLYN FOAM | GOOD | :: | 0.327 |
| 2 SURLYN FOAM/FILM | GOOD | :: | 0.319 |
| 3 PRESENT SYSTEM | GOOD | :: | 0.313 |
| 4 FRP/FILM | FAIR | :: | 0.313 |
| 5 PLYWOOD/FILM | GOOD | :: | 0.298 |
| 6 POLYURETHANE | POOR | :: | 0.295 |
| 7 FIBERBOARD/FILM | FAIR | :: | 0.291 |
| 8 ACRYLIC | POOR | :: | 0.286 |
| 9 AL/FILM | FAIR | :: | 0.263 |
| 10 FRP/PAINT | FAIR | :: | 0.258 |
| 11 PLYWOOD/PAINT | GOOD | :: | 0.248 |
| 12 FIBERBOARD/PAINT | FAIR | :: | 0.242 |
| 13 AL/PAINT | FAIR | :: | 0.228 |

Table 7-8 Summary of Judgments and Results for Model C
(Contracting Out of Dayboards)

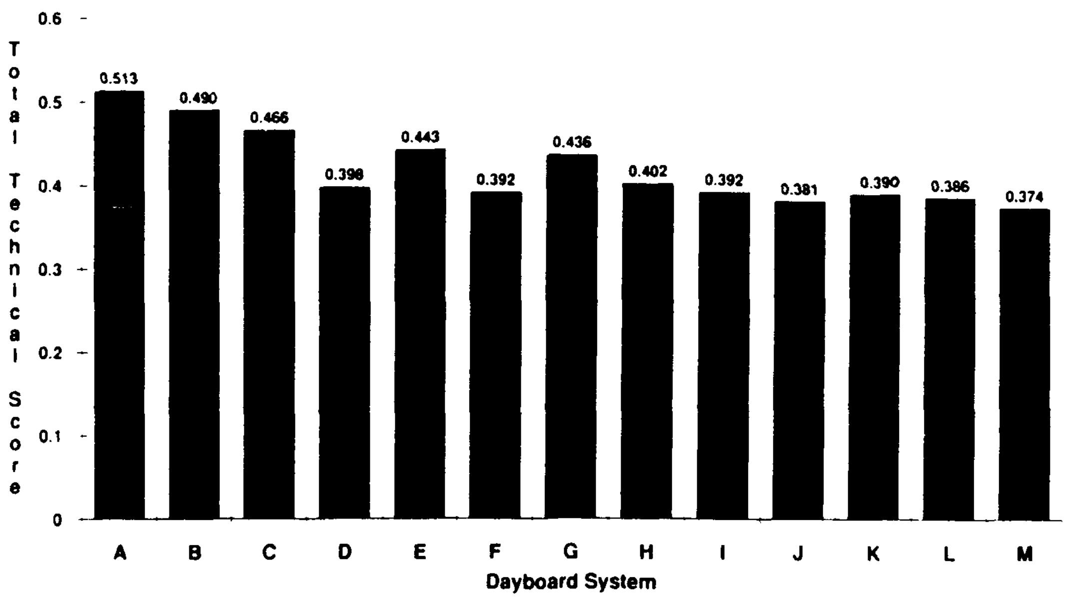
| ALTERNATIVES | CONSTRTN .1110 | INSTALTN .1110 | PERSAFTY .1595 | ENVSAFTY .2084 | SIG EFF .3662 |
|---|---|---|---|---|---|
| 1 SURLYN FOAM | NONE | EASY | MINOR | LITTLE | STANDARD |
| 2 SURLYN FOAM/FILM | NONE | EASY | MINOR | LITTLE | STANDARD |
| 3 PRESENT SYSTEM | NONE | EASY | NORMAL | HARMLESS | STANDARD |
| 4 FRP/PAINT | NONE | EASY | MINOR | LITTLE | STANDARD |
| 5 FRP/FILM | NONE | EASY | NORMAL | HARMLESS | STANDARD |
| 6 PLYWOOD/PAINT | NONE | AVERAGE | MINOR | LITTLE | STANDARD |
| 7 PLYWOOD/FILM | NONE | AVERAGE | NORMAL | HARMLESS | STANDARD |
| 8 FIBERBOARD/PAINT | NONE | AVERAGE | MINOR | LITTLE | STANDARD |
| 9 FIBERBOARD/FILM | NONE | AVERAGE | NORMAL | HARMLESS | STANDARD |
| 10 POLYURETHANE | NONE | AVERAGE | MINOR | LITTLE | STANDARD |
| 11 AL/PAINT | NONE | HARD | MINOR | LITTLE | STANDARD |
| 12 ACRYLIC | NONE | EASY | NORMAL | LITTLE | STANDARD |
| 13 AL/FILM | NONE | HARD | NORMAL | HARMLESS | STANDARD |

| ALTERNATIVES | AVAILBTY .0441 | | TOTAL |
|---|---|---|---|
| 1 SURLYN FOAM | GOOD | :: | 0.327 |
| 2 SURLYN FOAM/FILM | GOOD | :: | 0.327 |
| 3 PRESENT SYSTEM | GOOD | :: | 0.327 |
| 4 FRP/PAINT | FAIR | :: | 0.321 |
| 5 FRP/FILM | FAIR | :: | 0.321 |
| 6 PLYWOOD/PAINT | GOOD | :: | 0.311 |
| 7 PLYWOOD/FILM | GOOD | :: | 0.311 |
| 8 FIBERBOARD/PAINT | FAIR | :: | 0.305 |
| 9 FIBERBOARD/FILM | FAIR | :: | 0.305 |
| 10 POLYURETHANE | POOR | :: | 0.295 |
| 11 AL/PAINT | FAIR | :: | 0.294 |
| 12 ACRYLIC | POOR | :: | 0.294 |
| 13 AL/FILM | FAIR | :: | 0.294 |

## Expert Choice Model A1

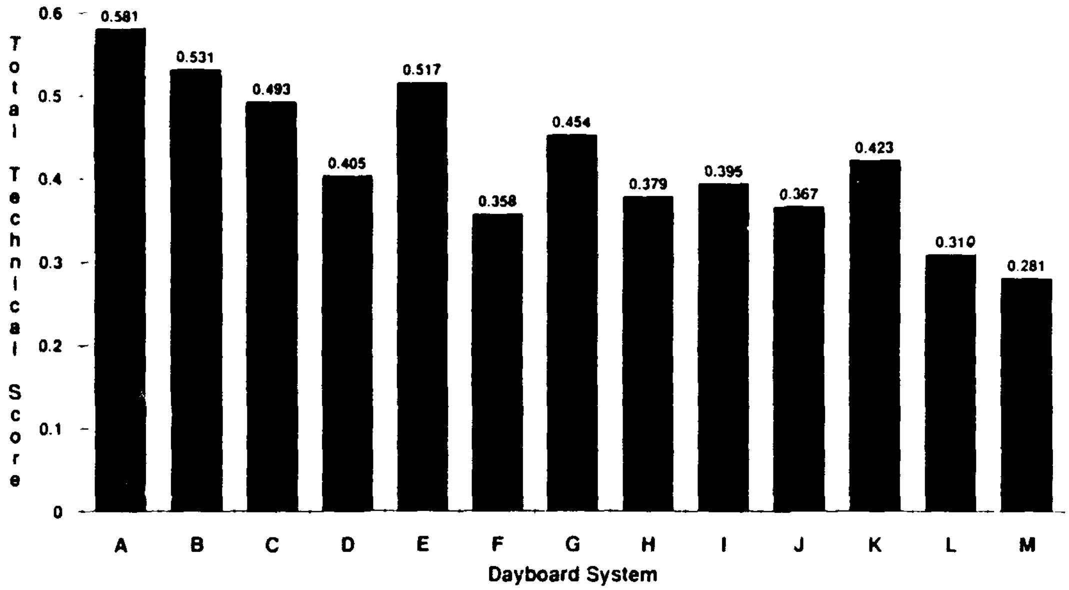



(a) Coast Guard Construction

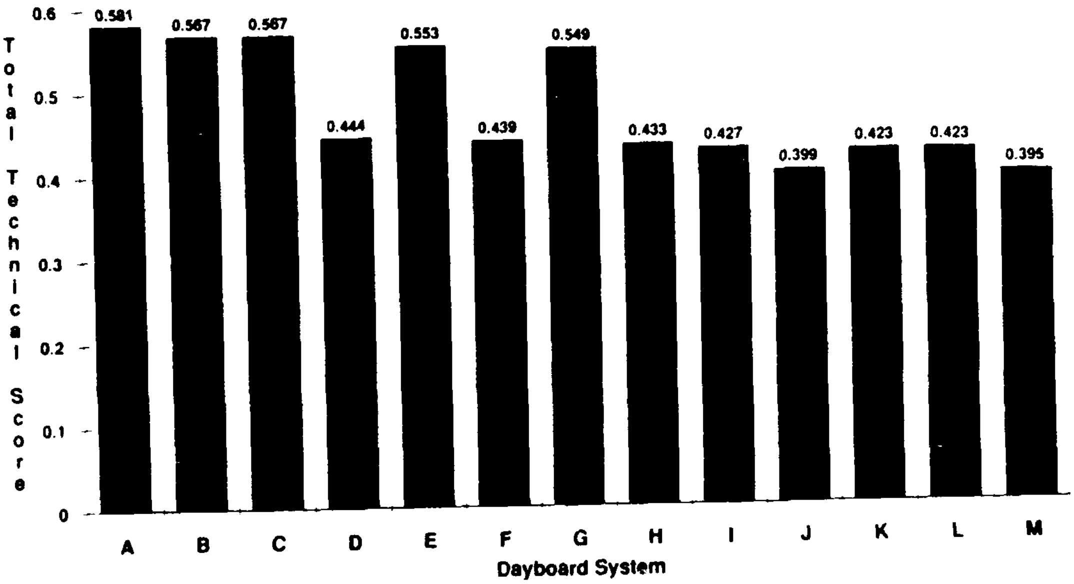



(b) Contracting Out of Dayboards

## Expert Choice Model A2

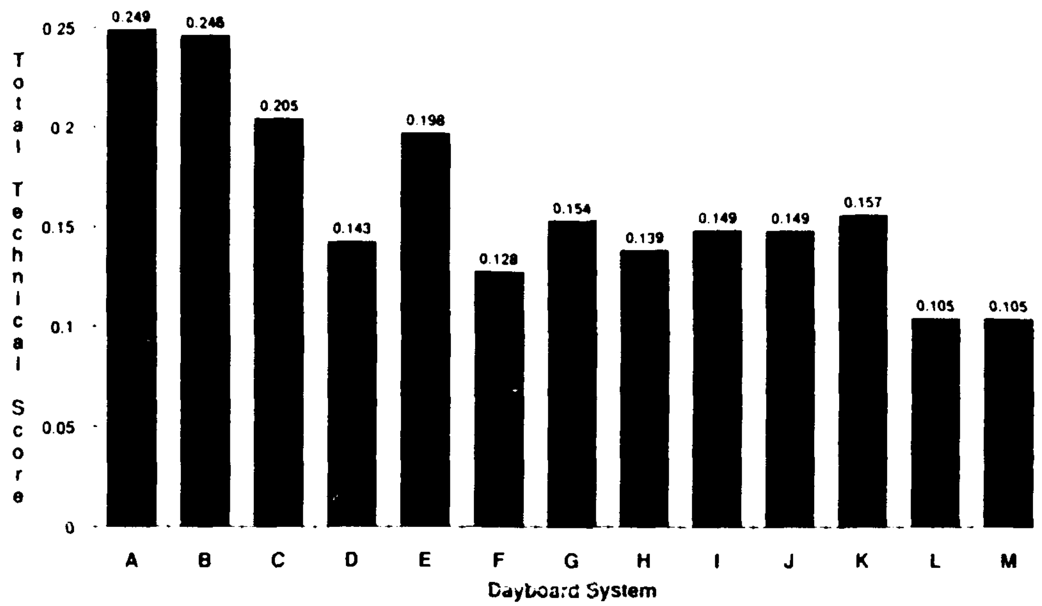



(a) Coast Guard Construction

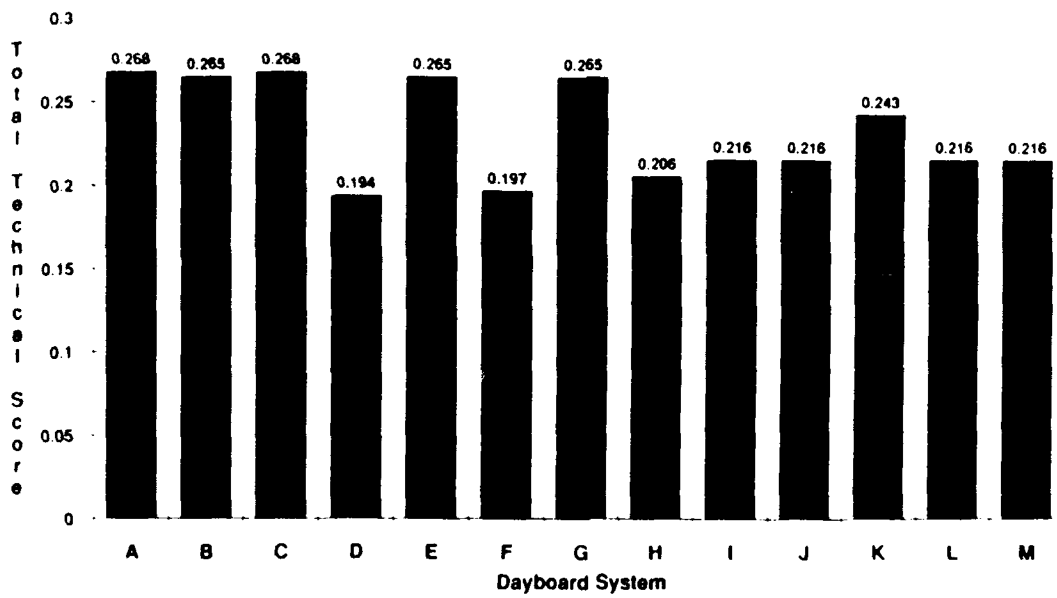



(b) Contracting Out of Dayboards

## Expert Choice Model B

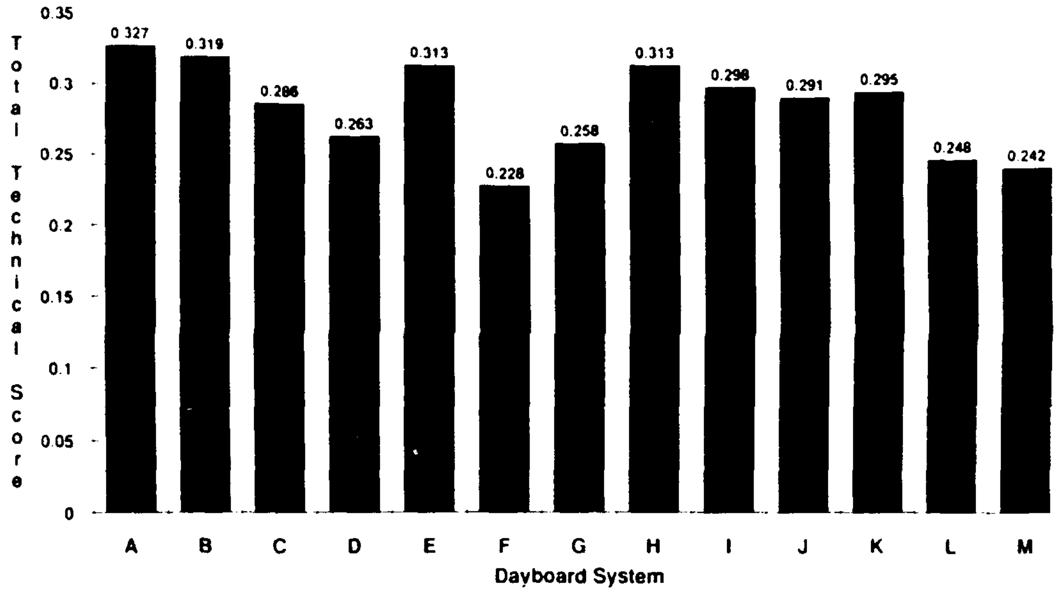



(a) Coast Guard Construction

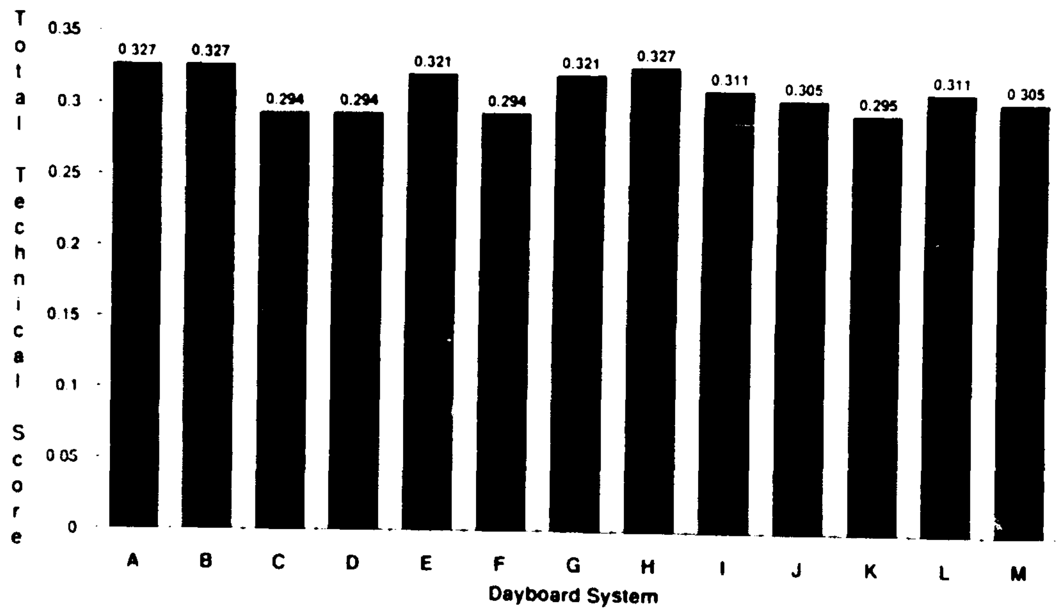



(b) Contracting Out of Dayboards

## Expert Choice Model C




(a) Coast Guard Construction




(b) Contracting Out of Dayboards